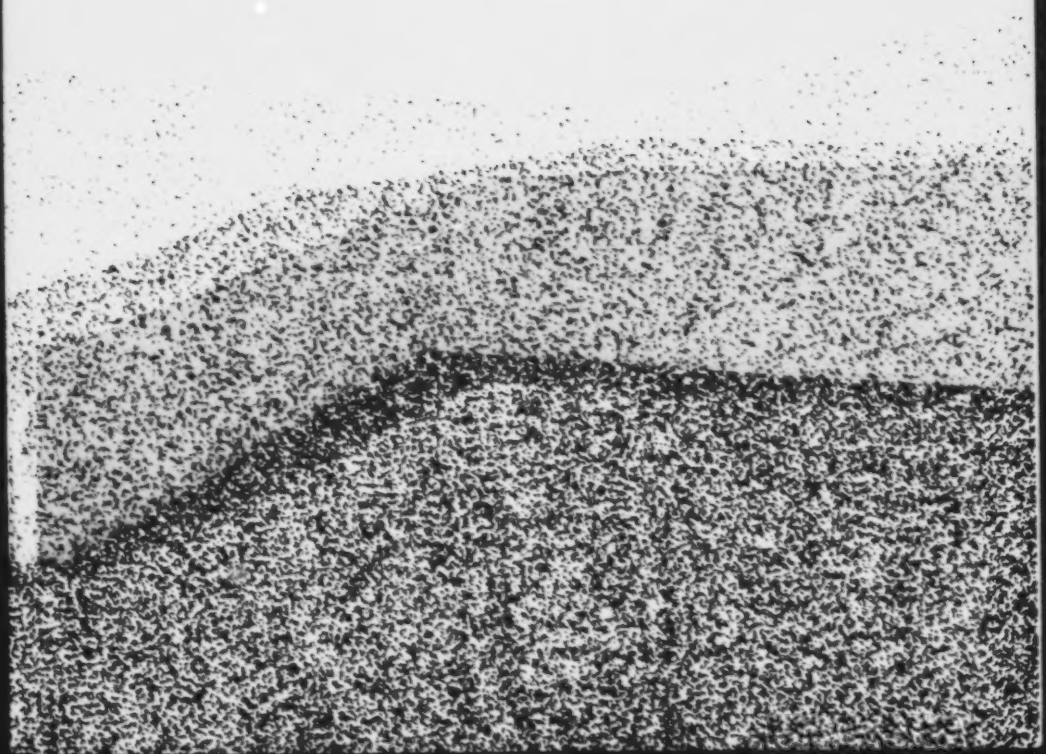
PRICING OF METALS

MARGARET E. SLADE



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Foreword

Increased volatity of prices for nonferrous metals has created serious problems for metal producers and consumers in the 1980s, affecting investment decisions, profitability, and trading in an unpredictable and frequently wasteful fashion. This study examines some of the underlying causes of instability in nonferrous metals, with particular attention to the changing roles of the two principal institutions for determining metal prices, the producer pricing system, and the major metal exchanges. It is hoped that the information provided, the analysis, and the conclusions, will clarify the issues involved and assist in decisions confronting nonferrous metal producers.

Views expressed are those of the author, and do not necessarily represent the views of the Centre for Resource Studies or its sponsors.

Margot J. Wojciechowski
Centre for Resource Studies

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Summary

Radical changes in the pricing of nonferrous metals occurred in the late 1970s and early 1980s. These led to a reduction in the role of producer pricing for some metals, the suspension of publication of producer prices for others, and increased reliance on metal exchanges for all. This study examines the causes and consequences of these changes.

Among the factors identified as contributing to the weakening of the producer-pricing system are the decline in horizontal concentration and vertical integration of some markets, the increase in importance of recycling of most metals, and the growth of international integration and government participation.

Both the level and variability of prices determined under the two systems are assessed. Contrary to the conventional wisdom, exchange-based prices were not lower on average than prices set by the major firms in the industry. The principal difference across systems is the higher degree of volatility of exchange prices.

The increased instability of nonferrous-metal prices in the 1980s was entirely explained by changes in underlying market-structure and organization variables. Foremost among these is the growth of importance of commodity exchanges. Other factors leading to volatility include a relatively large number of firms in the primary industry, low potential for substitution in the using sectors, and a high ratio of byproduct to primary production.

A fundamental difference between markets where prices are set by products and those with commodity exchanges is the scope for speculation that exchanges introduce. The tests conducted here provide evidence that speculation destabilizes prices in the markets studied. This conclusion is probably more surprising to academic economists than to industry-commodity specialists.

The switch to exchange-based pricing has considerable advantages as well as drawbacks. These include the introduction of hedging, which provides insurance to both buyer and seller, the adsorption of unwanted inventories, and greater price visibility. As the costs and benefits of the two systems vary from commodity to commodity, the existence of

two methods of price determination provides needed flexibility to markets that are in a state of transition.

Not only has the last decade seen fundamental changes in metal pricing, commodity exchanges have themselves undergone radical reorganization. In particular the London Metal Exchange, by far the most important market for nonferrous metals, was entirely restructured in 1987. This study provides a description of the way in which this market works and the reasons for the changes in its organization.

Résumé

Des changements radicaux concernant l'établissement des prix des metaux non-ferreux se sont produits à la fin des annees '70 et au début des annees '80. Ils ont conduits à la reduction du rôle des producteurs dans la détermination des prix pour certains métaux, a l'arrêt de la publication des prix des producteurs pour d'autres et finalement à l'augmentation de la dépendance sur les institutions d'échange de métaux, tel que le London Metal Exchange, pour tous les métaux non-ferreux. Cette étude examine les causes et les conséquences de ces changements.

Parmi les facteurs identifiés contribuant à la faiblesse du système de prix établis par le producteur, on retrouve: le déclin de la concentration horizontale et de l'intégration verticale pour quelques marchés, l'importance croissante du recyclage de la plupart des métaux et l'accroissement de l'intégration internationale et de la participation du gouvernement.

Le niveau et la variabilité des prix déterminés sous les deux systèmes sont évalués. Contrairement aux attentes populaires, les prix établis à l'intérieur des institutions d'échange n'étaient pas inférieurs, en moyenne, aux prix établis par les grandes firmes de l'industrie. La principale différence entre ces systèmes est la plus grande volatilité des prix sur les marchés d'échange.

L'instabilité accrue du prix des métaux non-ferreux dans les années '80 était entièrement attribuée aux changements sous-jacents la structure de marché et aux variables influençant l'organisation du marché. La plus évidente parmi celles-ci est la croissance en importance des échanges de marchandises. D'autres facteurs conduisant à cette volatilité incluent: le nombre relativement élevé de firmes dans l'industrie primaire, le faible potentiel de substitution pour les consommateurs intermédiaires, et le ratio élevé de sous-produits provenant de la production primaire.

Une différence fondamentale entre les marchés dans lesquels les prix sont fixés par les producteurs et ceux où ils le sont par les marchés d'échange est la possibilité de spéculation dans ces derniers. Les tests,

effectués dans cette étude, fournissent l'évidence que la spéculation déstabilise les prix dans les marchés étudiés. Cette conclusion est probablement plus surprenante pour les académiciens que pour les spécialistes de l'industrie.

L'utilisation du système de détermination des prix par les marché d'échanges a surtout des avantages. Ces derniers incluent la possibilité d'une couverture financière, laquelle procure une assurance aussi bien à l'acheteur qu'au vendeur, l'élimination des inventaires non désirés, et une plus grande visibilité des prix. Les coûts et les bénéfices reliés aux deux systèmes varient d'un produit à l'autre. L'existence des deux méthodes de détermination des prix procure la flexibilité nécessaire aux marchés en état de transition.

La dernière décennie a assisté à des changements fondamentaux dans le mécanisme de détermination du prix des métaux. À l'intérieur de cette même période, le marché d'échange a lui aussi subi des changements radicaux. Plus particulièrement le London Metal Exchange de loin le marché le plus important de métaux non ferreux, a été entièrement restructuré en '87. Cette étude fournie une description du fonctionnement de ce marché et les raisons des changements de son organisation.

1. INTRODUCTION

Nonferrous metal sales in North America have traditionally been conducted under a system known as producer pricing. Producer prices are set by the major firms in the industry. These prices change only at discrete intervals and tend to have smaller variances than exchange prices. Exchange or terminal prices, in contrast, are related to price quotations on the major metal exchanges, principally the London Metal Exchange (LME). These prices have traditionally been more influential outside of North America.

In the late 1970s and early 1980s, radical changes occurred in the pricing of many nonferrous metals. This period saw the virtual demise of the producer price of copper, the introduction of aluminum and nickel contracts on the LME, and the suspension of publication of producer prices for aluminum, nickel, and molybdenum. Even those industries where producer prices remained relatively stronger were affected. The same period saw a tendency for the producer price of lead to follow exchange prices more closely and, more recently, the widespread practice of discounting the producer price of zinc.

This report analyzes the changes that have occurred in nonferrous metal pricing in the last ten to fifteen years. It is not a study of how price levels are determined. Instead, it attempts to explain why producer prices have been weakened and to assess the consequences of increased reliance on metal exchanges.

Particular attention is paid to the causes and consequences of the price volatility that has characterized the nonferrous metal industries. This issue is of concern to producers and consumers alike as it makes planning for orderly growth difficult and contributes to the gluts and shortages that have plagued these industries.

The organization of the report is as follows. The next section analyzes metal pricing from an historic perspective. It looks at the last 100 years in an attempt to draw conclusions about price behavior in the long run. This analysis is quite different from the sections that follow, as it deals with the fundamental factors that determine price levels. Not only do later sections have a shorter time horizon, they also concentrate on different issues: the differences in price behavior across markets and pricing methods.

Chapter 3 describes the principal pricing mechanisms in detail. Particular attention is given to the major changes that have occurred in

the organization of the LME in the last year. In addition, it contains a discussion of the relative merits of producer and exchange pricing systems.

Chapter 4 discusses the factors that contribute to price instability. The object here is to discover how the structure of production and consumption and the organization of commodity markets affects pricing behavior. An attempt is made to generalize across markets rather than to analyze particular commodities.

Chapter 5, in contrast, deals with the individual commodities. Seven nonferrous metals were chosen for the analysis. The commodities are the six that are currently sold on the LME: aluminum, copper, lead, nickel, silver, and zinc. In addition, molybdenum was selected in an attempt to balance silver, which is not traded on a producer-price basis. Molybdenum was chosen as an important metal that is not traded on a metal exchange.

Chapter 6 contains a statistical analysis of nonferrous metal prices. Monthly data from the 1970-86 period are used in an attempt to decompose price variation into components that can be related to familiar economic and institutional factors. These factors include the market-structure and sales-organization variables that were found to be important in the analysis of chapter 4.

Finally, chapter 7 summarizes and concludes. Appendices at the end of the report contain detailed data documentation and statistical discussions.

2. HISTORIC METAL PRICES

This chapter takes a long-run view and analyzes a century of metal pricing. Long-run determinants are clearly different from the factors that influence month-to-month fluctuations, the subject of chapters 3-7.

The prices discussed here (and those shown in the figures) are for North American markets. Most metals are internationally traded, however, implying that prices in North America cannot deviate substantially from those in other regions for very long periods of time.

The behavior of metal prices often seems erratic and hard to predict. In the short run, prices fluctuate with random shocks in supply and demand, making it difficult to detect any regular behavior patterns. When examining the history of prices over a century, however, systematic tendencies can be seen and useful generalizations about price trends, both for individual metals and for the metals taken as a group, can be made.

Current-dollar price paths for many metals are broadly similar to one another. In general, prices reached a minimum around the turn of the century. There were sharp price increases around World War I, dramatic declines during the depression, and increases again after World War II. The 1950s and 60s, which were periods of relatively stable prices, were followed by the commodity boom of the early 1970s, when the prices of many metals reached unprecedented highs. After a decline, there was another rapid increase in the prices of many metals in the early 1980s. As with the earlier boom, much of the activity was fueled by speculation. The silver market played a particularly important role in the latter boom. Since that time, prices have again declined. Current-dollar, or nominal, prices are represented by the dashed lines in figures 1-7.[1]

Current-dollar prices are highly correlated with the economy-wide rate of inflation. To detect patterns that are unique to the metals, therefore, it is necessary to correct for more general price fluctuations. That is, any trends that are purely inflationary or recessionary must be removed. This is achieved by dividing each price series by the U.S. wholesale price index (1986 = 1.0). The result is a set of real, or constant-dollar prices: prices expressed in terms of a hypothetical dollar

[1] Most of the price series shown in the graphs are producer prices. More precise descriptions of the individual series can be found in the data appendix.

of constant value. These constant-dollar prices are discussed throughout the remainder of the chapter.

Other deflating indices, such as the consumer-price index or the wholesale commodity-price index could have been used. Aggregate price indices, however, tend to move together. The conclusions drawn here, therefore, would not be affected by the choice of deflator. Real price paths are represented by the solid lines in figures 1-7.

Each metal has a unique price path. Certain general tendencies, however, emerge from the diverse behavior patterns. The most important factors that affect long-run trends in metal prices are growth of metal demand, changes in mining and metallurgical techniques, discovery of new deposits, and depletion of high-grade orebodies. The first three factors tend to predominate in the early phases of a metal's life cycle, whereas the fourth may be more important later on. Thus it can be expected that real metal prices will initially fall, but, unless close substitutes can be found, they may eventually rise. Certainly the empirical evidence points to a decline in real-metal price up until the middle of this century.[2] The reasons why this might be so are therefore summarized here.

In the initial phase of a metal's commercial history, many factors can contribute to falling costs. Metal mining and processing is characterized by substantial economies of scale. For example, a single mine can supply ten percent of current consumption of some metals. When the market is new, mines and smelters tend to be too small to be fully efficient. The growth in demand as additional metal uses are discovered, therefore, allows mining companies to exploit cost-lowering economies of scale.

Learning-curve effects can also be important. As companies gain experience in mining, smelting, and refining, they may discover new techniques that lower costs. Costs may therefore fall with cumulative metal production. In addition, there may be improvements in extractive and metallurgical technology that are not specific to an industry but may be applicable across broad groups of industries. For example, the dis-

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[2] H.J. Barnett and C. Morse, *Scarcity and Growth* (Baltimore: John Hopkins University Press, 1963); H.J. Barnett, "Scarcity and Growth Revisited", in *Scarcity and Growth Reconsidered*, V.K. Smith (ed.) (Baltimore: Johns Hopkins University Press, 1979); M.E. Slade, "Trends in Natural-Resource-Commodity Prices: An Analysis of the Time Domain", *Journal of Environmental Economics and Management*, 1982, no. 9, pp. 122-137.

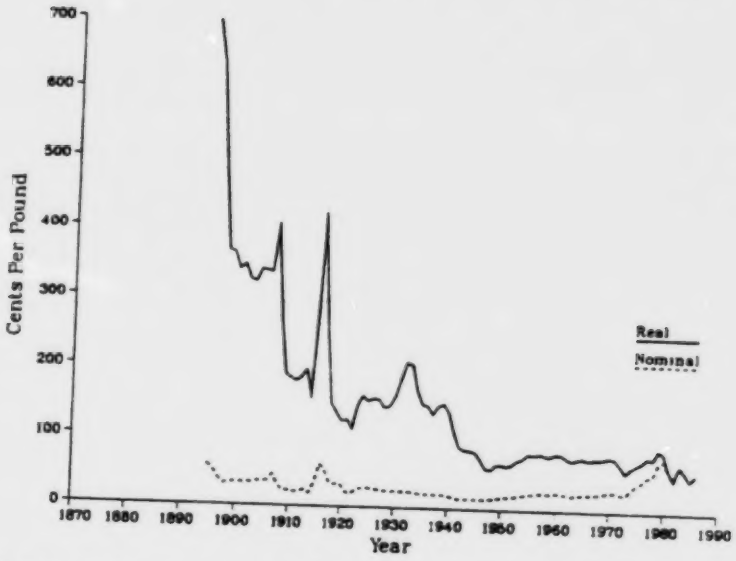

Figure 1. Aluminum: real and nominal prices, 1895-1986, $ U.S.

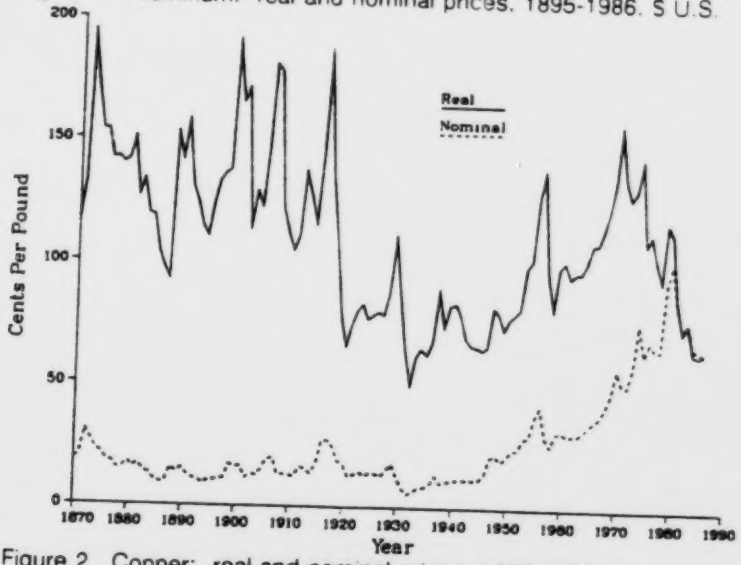

Figure 2. Copper: real and nominal prices, 1870-1986, $ U.S.

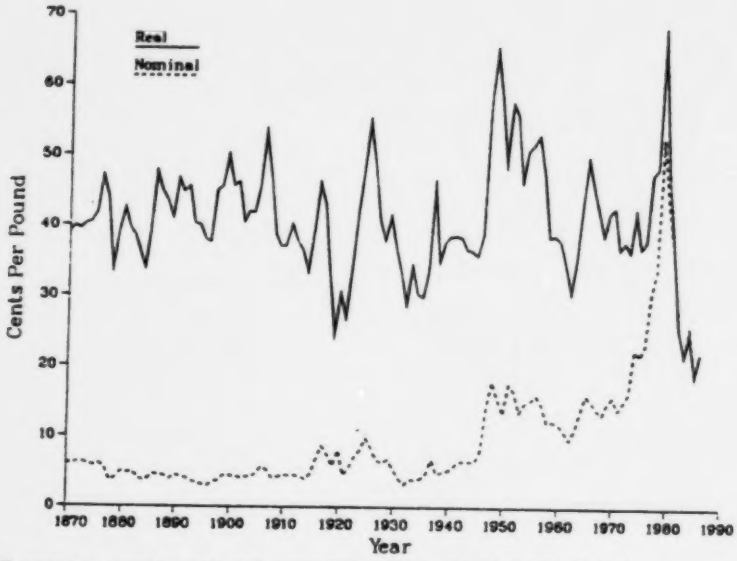

Figure 3. Lead: real and nominal prices, 1870-1986, $ U.S.

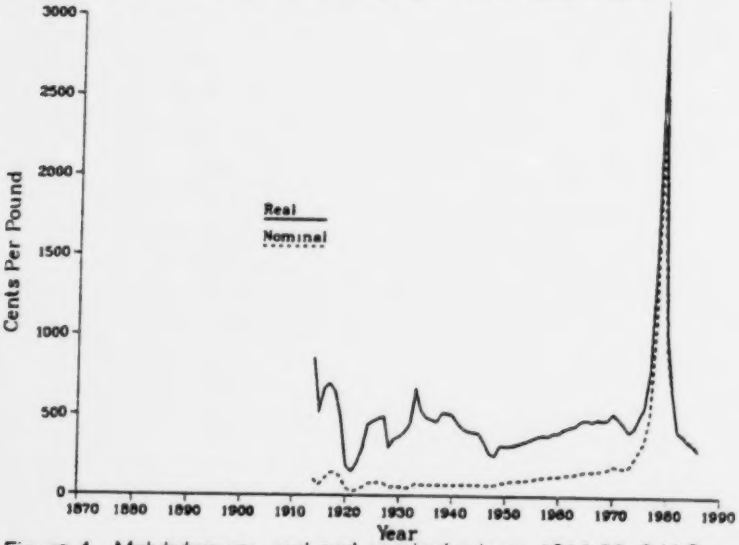

Figure 4. Molybdenum: real and nominal prices, 1914-86, $ U.S.

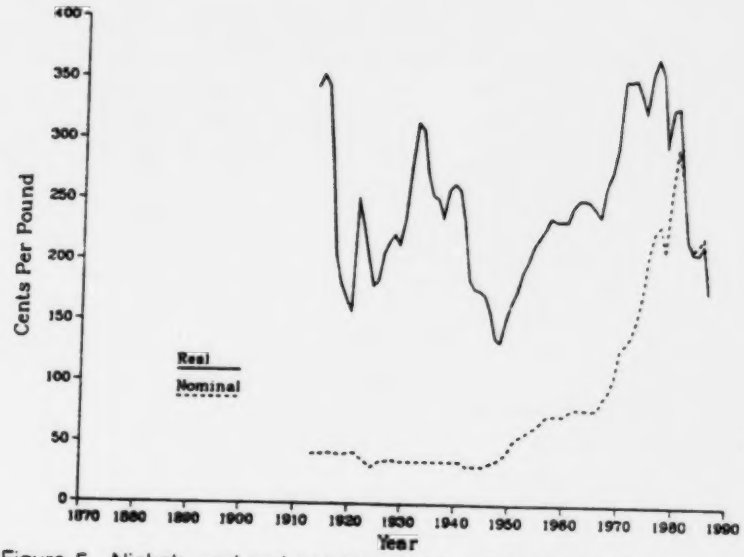

Figure 5. Nickel: real and nominal prices. 1913-86. S U.S.

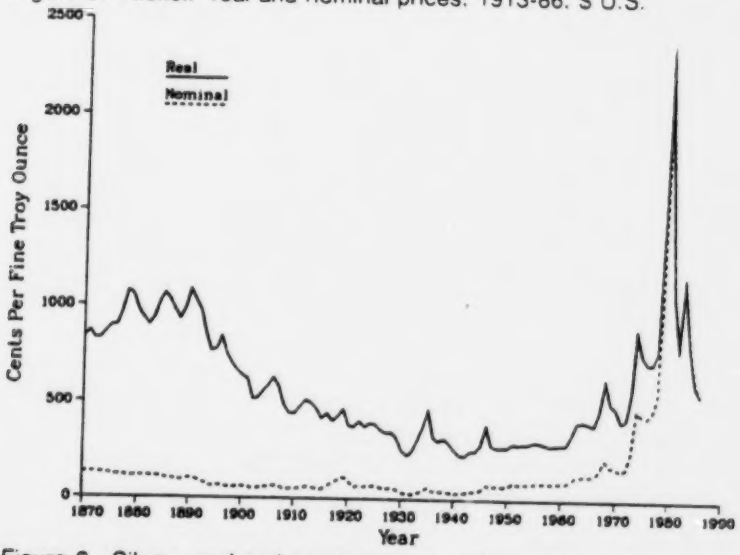

Figure 6. Silver: real and nominal prices. 1870-1986. S U.S.

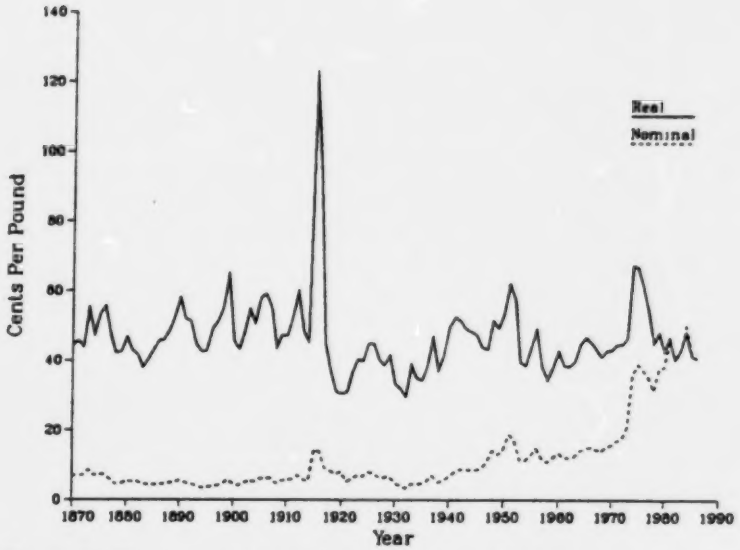

Figure 7. Zinc: real and nominal prices, 1870-1986, $ U.S.

covery of froth flotation lowered processing costs for many sulfide minerals.

Technical change can take place on the production or on the consumption side of a market. If it occurs on the production side, it generally lowers costs and therefore price. If it occurs on the consumption side, its effect is more ambiguous. It can, however, increase metal demand and allow mining companies to exploit economies of scale. When this is the case, the change will exert downward pressure on price in the long run.

The discovery of new deposits can increase metal supply and cause prices to fall. Even when new discoveries do not lower prices immediately, the expansion of known reserves can postpone the onset of higher costs due to the depletion of high-grade orebodies.

There are thus many factors that can lead to falling real metal prices. A comparison of figures 1-7 shows that aluminum is the commodity that exhibits the most dramatic real-price declines.

The period when the trend is downward is often followed by one where the trend is flat or nonexistent. This period can be very long, as

for lead and zinc, or fairly short lived. In this trendless period, production growth rates are often steady but not dramatic, and the average grade of ores mined falls only slowly.

Unless close substitutes can be found, however, a final phase of rising prices can occur. As high-grade deposits are depleted, newly discovered deposits may tend to have lower metal content, be more deeply buried, of lower grade, or in thinner veins. In addition, if prices are to rise, the rate of introduction of cost-lowering techniques must be insufficient to offset the rise in costs due to depletion. This has long been the case for tin and mercury, for example (not shown in the graphs). An increase in price will, in general, cause consumers to conserve on use, and therefore consumption growth is expected to be small or negative for metals that experience rising costs due to depletion.

The copper industry illustrates the historic counterbalancing influences of improvements in technology and deterioration in ore quality in determining production cost. In the first 75 years of this century, the average grade of copper ores mined in the U.S. declined from about five percent to 0.7 percent.[3] In spite of this decline in grade, real copper prices fell until about 1940. The fall in price was due to technological developments in the early part of the century, particularly the advent of large earth-moving equipment, which made possible the open-pit mining of extremely low-grade orebodies, and the the discovery of froth flotation, which made concentration of low-grade sulfide ores economical.

By 1940, however, the switch to this new technology had reached its natural limits. Since that time, in spite of new mining and processing techniques, the decline in grade has become an important factor in determining cost. In recent years, technological emphasis has been on energy-saving features and improved environmental acceptability. The former lowers costs but the latter tends to increase them. These factors have contributed to the post-war trend in real copper price which, with the exception of the mid-1980s, has been positive.

Petersen and Maxwell document the history of the relative impact of ore grade and technology on the cost of other metals (silver, tin, lead, zinc, and iron) and claim that these factors have been much more

[3] U.S. Bureau of Mines, *Mineral Facts and Problems*, (Washington, D.C.: U.S. Department of the Interior, 1975).

important than the discovery of new deposits in the historic determination of metal prices.[4]

Thus far we have examined long-run metal-price trends.[5] These trends, however, are often swamped by short-run fluctuations. Figures 8-21 attempt to assess the magnitude of fluctuations within a decade relative to the 100-year history of metal prices.

Figures 8-21 are known as histograms. To interpret these figures, one must perform the following conceptual experiment. Suppose that we have 100 years of data on real prices for a commodity, and suppose, in addition, that the maximum price observed in this 100-year period was $1.00 per pound. The height of each bar in the graph then shows the number of years in which the historic price fell within the limits shown on the horizontal axis.

For example, figure 8 shows that, when prices are normalized so that the maximum observed is $1.00, the normalized price of aluminum was between 10 and 15 U.S. cents per pound in 32 of the 100 years. Prices have been normalized so that comparisons can be made across commodities. Histograms have been constructed in both real U.S. and real Canadian dollars.

Three normalized prices are indicated on each histogram. The first is the minimum price in the 1980-86 period, the second is the maximum in that period, and the third is the price in 1986. By observing these prices we can see if within-decade price fluctuations are large or small relative to the 100-year price history.

First, consider the U.S.-dollar histograms. These histograms reveal that the only commodity for which 1980 prices tend to cluster at the low end of the scale is aluminum. All three of the arrows that indicate particular 1980 aluminum prices fall either on the historically most common price (the highest bar on the graph) or to its left. Silver prices, in contrast, tend to cluster at the high end of the scale, with all three arrows to the right of the most common price. Prices in the 1980s for all five

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[4] U. Petersen, and R.S. Maxwell, "Historical Mineral-Production and Price Trends", *Mining Engineering*, 1979, pp. 25-34.

[5] Those wishing to read more about long-run metal-price trends are referred to M.E. Slade, "Trends in Natural-Resource-Commodity Prices: An Analysis of the Time Domain", *Journal of Environmental Economics and Management*, 1982, no. 9, pp. 122-137; and "Prices of Metals: History", in M.B. Bever (ed.) *Encyclopedia of Materials Science and Engineering*, (Oxford: Pergamon Press, 1986).

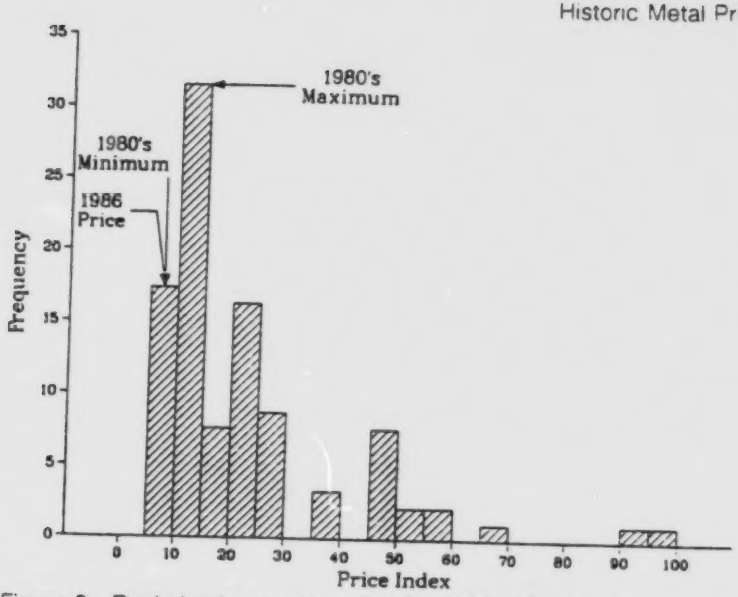

Figure 8. Real aluminum prices, $ U.S., 1895-1986, frequency distribution

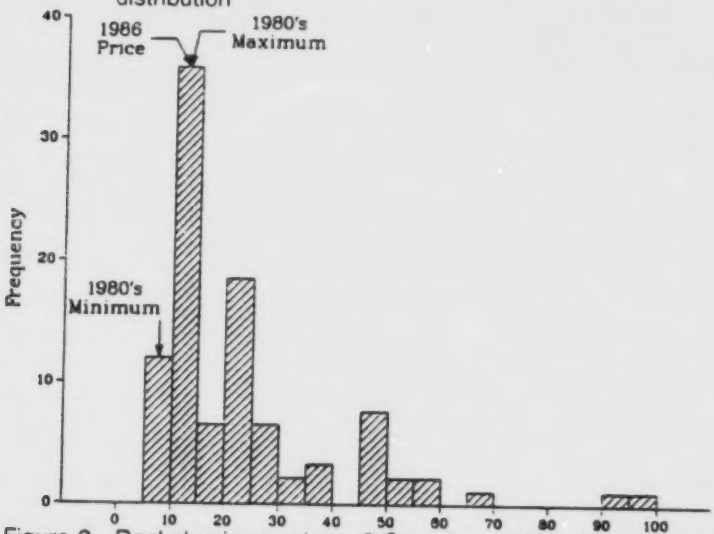

Figure 9. Real aluminum prices, $ Canadian, 1895-1986, frequency distribution

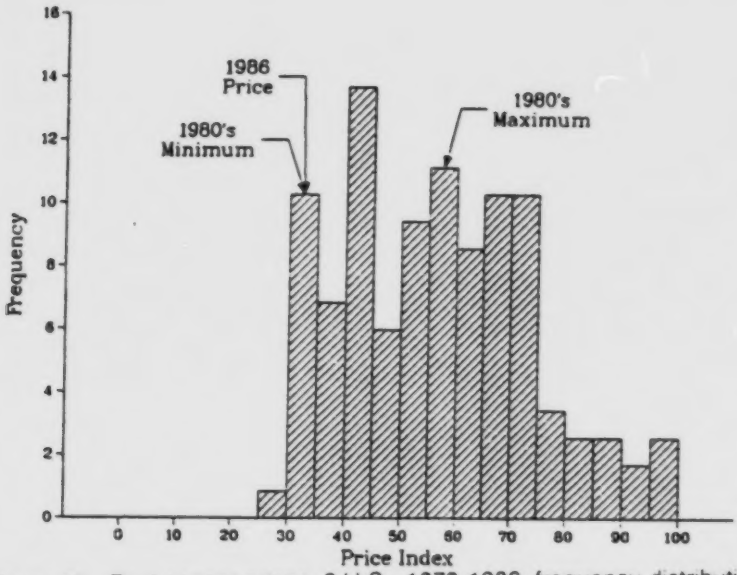

Figure 10. Real copper prices, $ U.S., 1870-1986, frequency distribution

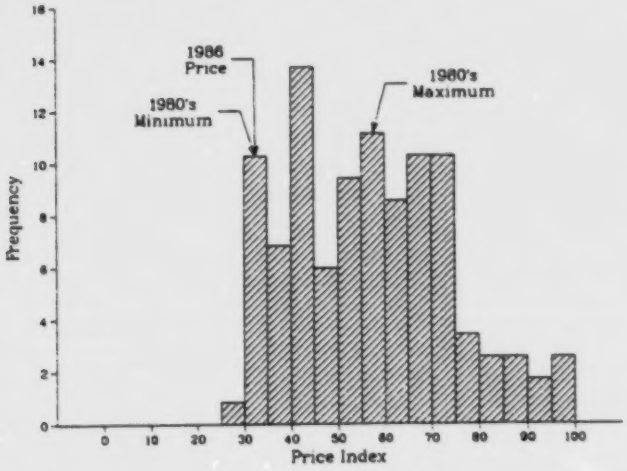

Figure 11. Real copper prices, $ Canadian, 1870-1986, frequency distribution

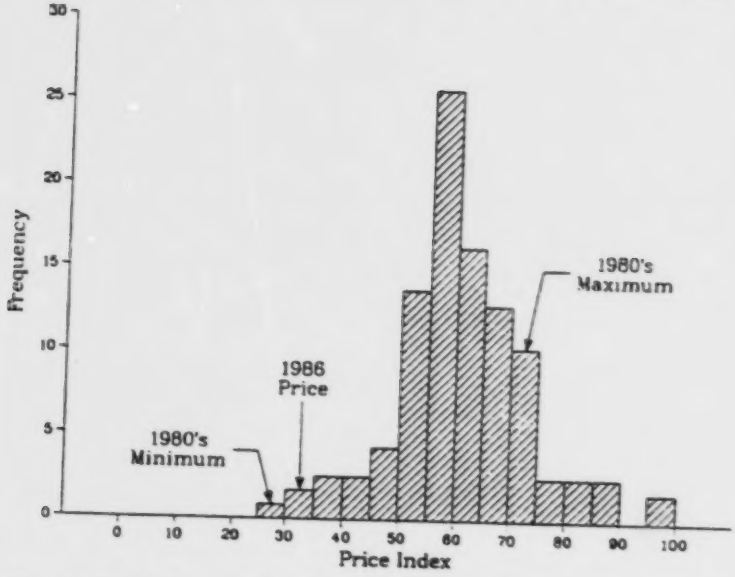

Figure 12. Real lead prices, $ U.S., 1870-1986, frequency distribution

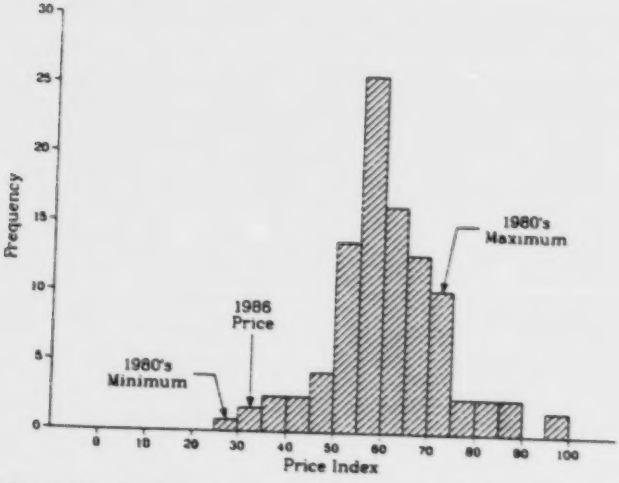

Figure 13. Real lead prices, $ Canadian, 1870-1986, frequency distribution

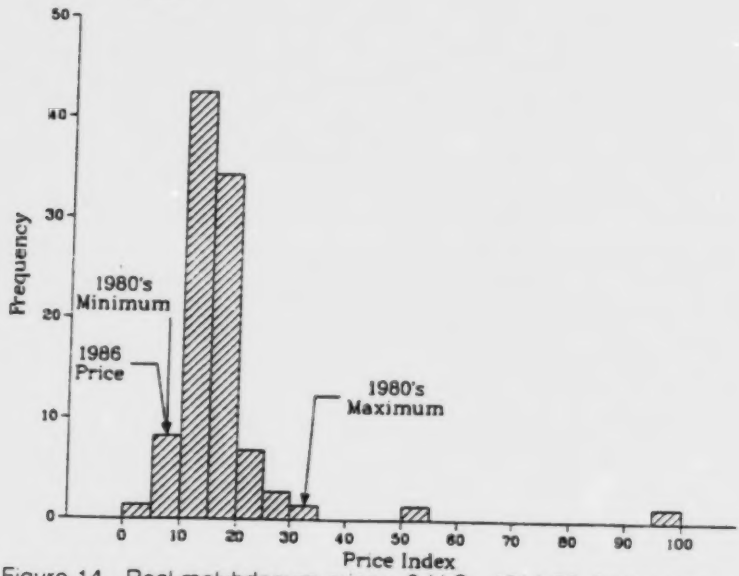

Figure 14. Real molybdenum prices, $ U.S., 1914-86, frequency distribution

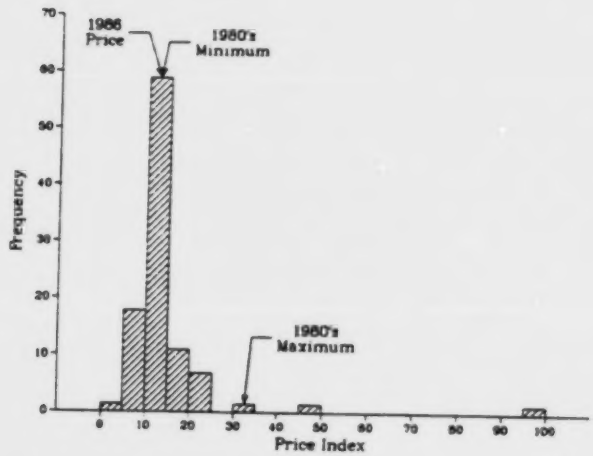

Figure 15. Real molybdenum prices, $ Canadian, 1914-86, frequency distribution

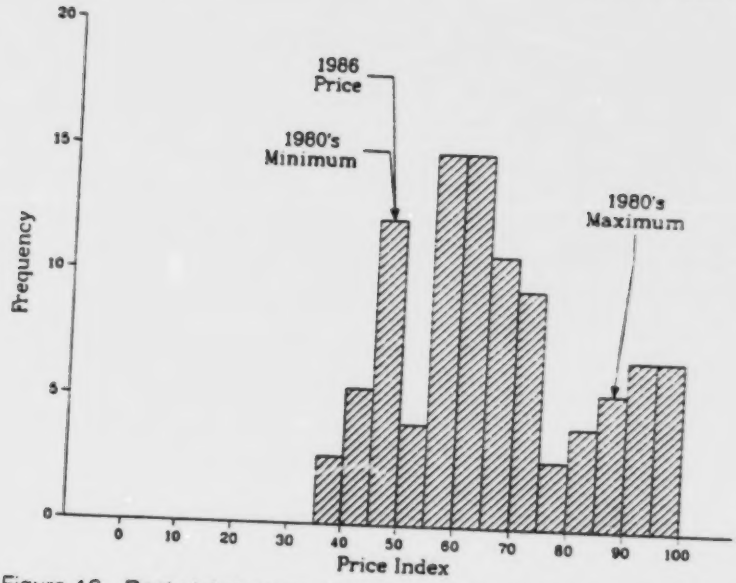

Figure 16. Real nickel prices, $ U.S., 1913-86, frequency distribution

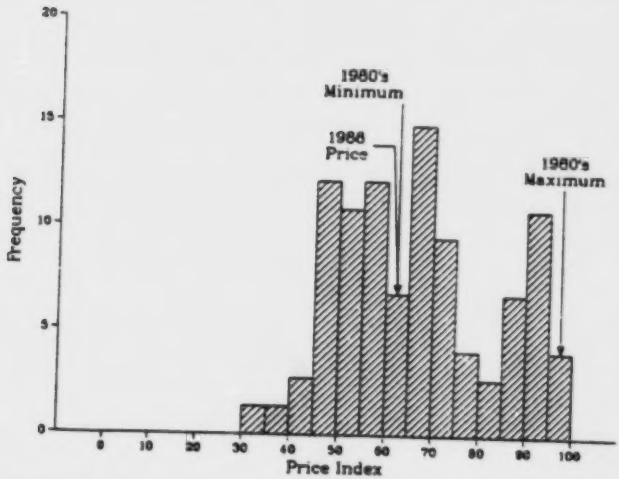

Figure 17. Real nickel prices, $ Canadian, 1913-86, frequency distribution

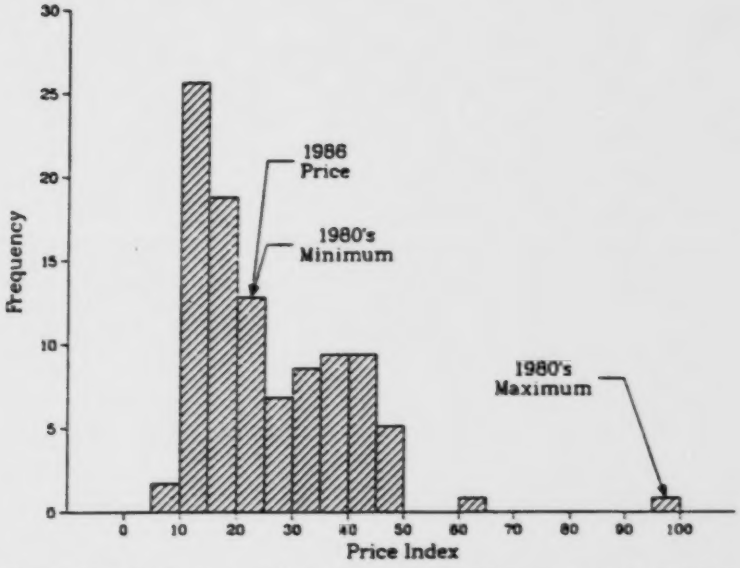

Figure 18. Real silver prices, $ U.S., 1870-1986, frequency distribution

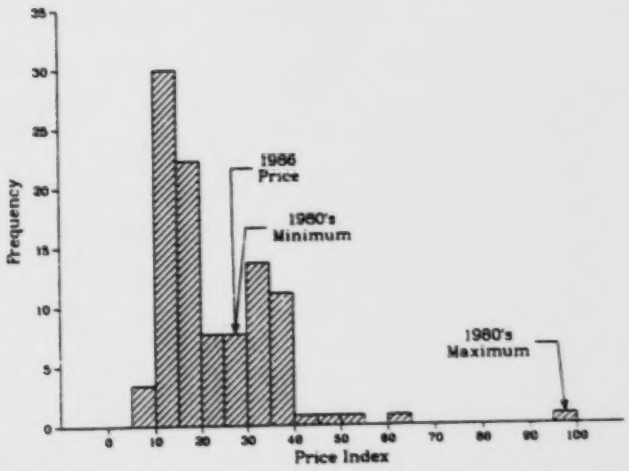

Figure 19. Real silver prices, $ Canadian, 1870-1986, frequency distribution

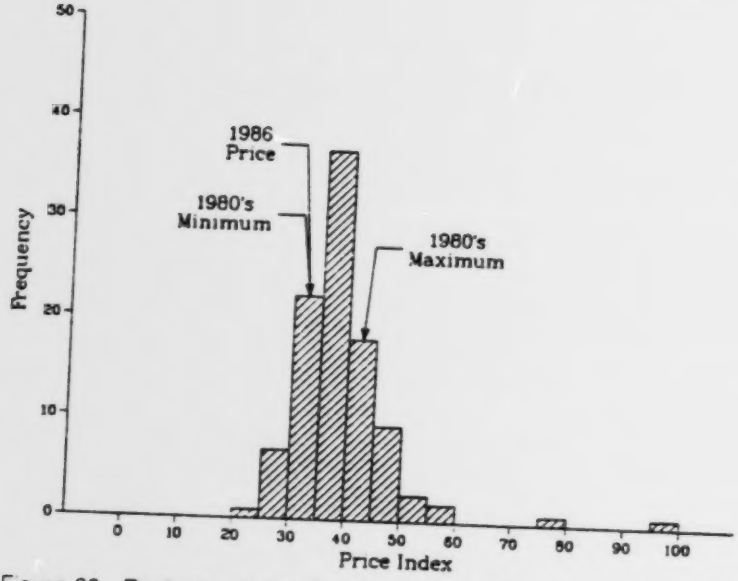

Figure 20. Real zinc prices, $ U.S., 1870-1986, frequency distribution

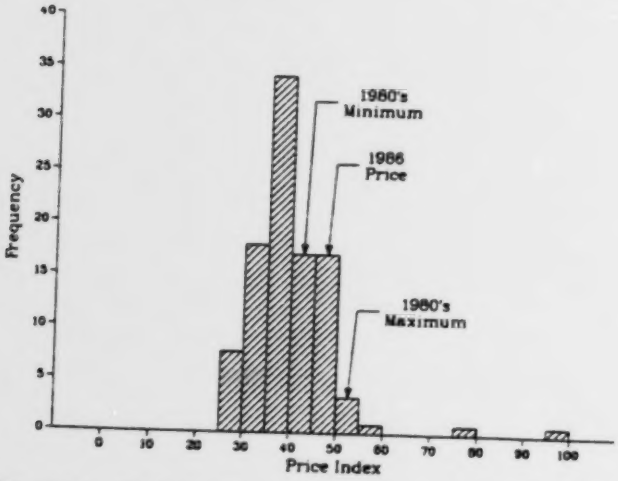

Figure 21. Real zinc prices, $ Canadian, 1870-1986, frequency distribution

of the remaining commodities, however, fall both to the left and to the right of the peak. This indicates that the real prices of these commodities in the current decade have been both on the up and on the down side of historic averages.[6]

Canadian-dollar histograms were constructed from U.S.-dollar prices by applying the relevant exchange rate in each year. These histograms show the influence of exchange-rate fluctuations in determining the prices that are of interest to producers whose costs must be paid in Canadian currency. Historic plots of Canadian-dollar prices (the counterparts of figures 1-7) are not shown because they look too similar to the U.S.-dollar time-series plots.

Both sets of histograms (U.S. and Canadian dollar) show that within-decade fluctuations are surprisingly large relative to the 100-year price history. That is, the three arrows span a wide range on the histograms. The rest of this study examines these short-to-medium-run price fluctuations in greater depth.

[6] The most-common price or mode is not the same as the historic average or mean. 1980s prices for most commodities, however, fall on both sides of both the mean and the mode.

3. PRICING MECHANISMS

This chapter contains an analysis of producer and exchange pricing mechanisms. After each has been described, its relative merits are discussed. An attempt is made to weigh the pros and cons of each system and to assess its strengths and weaknesses in an impartial fashion.

The discussion of the London Metal Exchange (LME) is fairly detailed. Because the recent reorganization of this exchange has led to substantial changes in its operation, it is worth devoting space to a comprehensive discussion of the way in which this market works. Both historical and contemporary aspects are considered. Those uninterested in institutional details can read the next paragraph and then skip this discussion without losing continuity.

Commodity-exchange prices are related to price quotations on the major metal exchanges, the LME and Comex. These exchanges are basically hedge and speculative markets, although physical turnover can be substantial. Prices are competitively determined in daily auctions where dealers make bids and offers and, contracts are issued when the bids and offers are accepted. Exchange markets are much more important than their physical volume might indicate. A very large quantity of metal sells at prices based on LME quotes without actually being sold on an exchange.

Commodity-Exchange Prices

The London Metal Exchange

History and Background[1]

Commodity markets in London began developing into their present form in the middle of the nineteenth century. At first, ship cargoes were sold forward "on arrival of ship". The next step was to trade in fixed forward

[1] Much of the information contained in this section was found in R. Prain, *Copper: The Anatomy of an Industry*, London: Mining Journal Books, Ltd., 1975 and in Rudolf Wolff & Co. Ltd., *Wolff's Guide to the London Metal Exchange*, 2nd and 3rd editions, (London: Metal Bulletin Books, 1980).

periods. These practices helped both producers and consumers protect themselves against financial risk.

It was soon necessary to have a regular meeting place for the purposes of transacting business. The Jerusalem Coffee House was the first unofficial headquarters for the infant metal exchange. Few records, however, survive from these early meetings.

Three developments were fundamental in the evolution of a modern market: the introduction of a standard contract, the change from forward dealing for delivery to hedging, and the growth of speculation. In addition, technological developments such as the linking of continents by submarine telegraphy enabled rapid transmission of information.

By the 1870s London had a vigorous and well-established market, and in 1876 the London Metal Exchange company was formed. This new company found quarters in Lombard street. It was at this time that the custom of dealing in a "ring" developed, a practice that continues today. It became the custom for some member to draw a large chalk circle on the floor and to call "ring, ring". Members then stood in their recognized places and cried their bids and offers across the floor.

Curiously, it was this Ring dealing that led to the Exchange's first major controversy. Older and more conservative members disliked the new practice, claiming that it gave too much scope to speculators. They therefore ordered that the chalk line no longer be marked on the floor. The dispute among members that arose from this order eventually gave rise to a constitution that remained in effect until July 1987. In addition, the reorganized group moved into new quarters in Whittington Avenue, the home of the Exchange until 1980, when the pressures of space necessitated the move to the present location in Plantation House.

Superficially, little has changed since the move to Whittington Avenue. The chalk line on the floor was replaced by curved benches, divided into seats allocated to the firms authorized to deal. Members of the Exchange, however, continued to transact business by means of open outcry across the floor. In addition, Ring dealing in each commodity was still limited to short regular intervals in the morning and the afternoon.

The influence of the LME, however, continued to grow. The London price became the effective world price for many metals, irrespective of the volume of metal in which it physically dealt. Cabled to the ends of the earth, daily official prices established by Ring dealings governed the terms on which copper, tin, lead, and zinc were bought and sold throughout the world.

The first commodities traded on the LME were copper and tin. Silver was introduced in 1897,[2] and lead and zinc were included in the main Ring in the early 1900s. Aluminum and nickel, recent additions, had to wait until the 1978-79 period to be traded. Thus, by 1980, there were seven commodities sold. In 1985, however, tin trading was suspended (see the section on recent crises) leaving the number of active metals at six.

There have been other recent innovations such as increased liberality towards foreigners as members. The most fundamental structural changes, however, took place in 1987.

The LME Today[3]

Unprecedented growth of financial markets in London in the 1980s led to increased misgivings about the nature of regulation of investment business in the U.K. Concern over metal trading in particular was aggravated by the tin crisis of 1985. The Financial Services Act of 1986 was an attempt to promote efficiency, competitiveness, and confidence in the financial sector while maintaining a flexible structure.

The Financial Services Act laid out specific criteria required for recognition of an exchange as a "Recognized Investment Exchange". The most fundamental change mandated by the Act was a switch from a principals' market (a market where members act as principals for the transactions that they conclude across the Ring and with their clients) to a clearing-house system. A clearing house is an independent body that clears and guarantees business transacted between member brokers. The newly-established International Commodities Clearing House (ICCH) guarantees contractual performance in the market, regardless of any member's failure.

A consequence of the new clearing-house system was the introduction of margins. An initial margin (usually about ten percent) is paid for every trade processed through the clearing system. In addition, variation margins may be collected as often as daily if the market moves against the trade and therefore increases the risk to the clearing house.

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[2] But, see page 76.

[3] Most of the information for this section comes from Rudolf Wolff & Co Ltd., *Wolff's Guide to the London Metal Exchange*, 2nd and 3rd editions, (London: Metal Bulletin Books, 1987).

The LME opted to retain its system of settlement on due date when it made the switch to a clearing-house system. This means that funds may not be withdrawn during the life of a trade. Credits are received (with interest) at the time the trade is closed.

The LME system of margins is unusual in that it applies only to the net position of brokers. The ICCH looks at a member's total exposure when calculating margins. In-credit positions can therefore compensate losses on risk positions.

Ring membership continues to be limited to 36, the number of seats in the Ring. A Ring member must be an entity incorporated in the UK with offices in London. It is also possible to be an associate or an individual member, with less stringent requirements.

Trading is carried out by dealers calling out bids and offers to the Ring. Bids and offers may not be directed at individual firms but must be to the entire Ring. This custom is known as the open outcry system.

Trading in each commodity is limited to five-minute periods, two in the morning and two in the afternoon. Typically, Ring dealing begins with members offering to lend or borrow metal on various dates. Then some dealer will open with an outright bid or offer. As the end of the five-minute period approaches, trading appears to be chaotic to the casual observer. Market clerks, however, stand behind each dealer and record each transaction. Each seller's clerk must check each transaction at the end of the Ring with his counterpart on the buying side. Any disputes are settled immediately by the clerks or dealers.

Three members are selected weekly from the body of Ring members to form a quotations committee. Committee members must be present at the morning sessions, for it is their duty to establish official prices. Prices are usually selected as the last best bid and offer prevailing at the close of the Ring. The committee has the right, however, to disregard the last unsatisfied bid or offer if it feels that it was unrepresentative of the tone of the market. Agreed-upon prices are then announced as the day's official buyers' and sellers' prices for cash, three months, and fifteen months.

In addition to Ring dealings, trading in options has grown substantially in the last five years. An option gives the buyer the right, but not the obligation, to buy or sell (or both) an agreed quantity of metal for delivery at a fixed price in the future. In order to gain this right, the holder of the option must pay the seller a premium. The appearance of traded options on the official market coincided with the advent of the clearing house. Options offer greater flexibility in hedging operations.

Figures 22-23 show LME sales volume and inventories in recent years. For comparison purposes, figure 24 shows Western-world consumption of the same commodities.[4] It can be seen that aluminum sales rapidly approached those of copper. Nevertheless, the importance of aluminum on the LME underestimates its importance in the world. It can also be seen that the LME and world roles of lead and zinc are reversed. That is, lead sales outstrip zinc sales on the Exchange but not in the world. As discussed later, the LME is not an important market for zinc. Finally, nickel sales increased after its introduction in 1979 but this market is still thin.

Recent Crises

Two crises have challenged the very existence of the LME and other metal exchanges in recent years. The first was the silver-price manipulation that occurred in the 1979-80 period and the second was the financial crisis in the tin market that caused the indefinite suspension of the LME tin contract.

The silver manipulation is associated principally with the name of Nelson Bunker Hunt, although other speculators were involved. This attempt to corner the silver market, like most previous attempts to manipulate metal markets, eventually failed. Prior to failure, however, the disturbance in the pattern of silver prices was enormous (see figure 46 below). In the space of a year, silver prices rose from under $6 to over $38 per troy ounce, only to come tumbling back down again.

During the crisis, all formal silver markets were under considerable stress. The LME, however, which was at the time still a principals' market, adopted a laissez-faire attitude. The Commodity Exchange of New York (Comex), in contrast, instituted frequent changes in the level and structure of margin calls and trading limits. As a result, when the crisis was over there were numerous law suits against Comex. Disgruntled speculators who lost large sums of money charged that the frequent rule changes were bewildering and contributed to their financial loss.

The tin crisis of 1985-86 had a much more profound impact on the LME. The affair involved traders around the world, but the exchange bore the brunt of what was at one point a £900 million default.

[4] Silver is not shown because its physical (but not its dollar) volume is small.

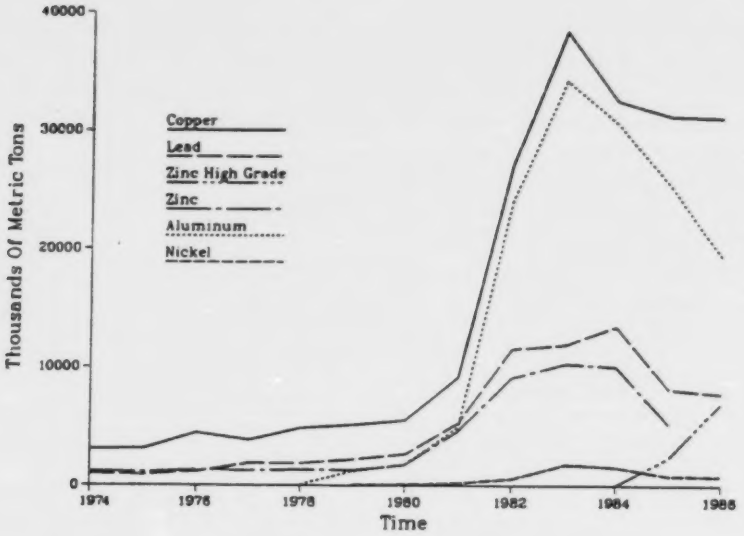

Figure 22. LME Sales Volume: 3 Months, Yearly, 1974-86

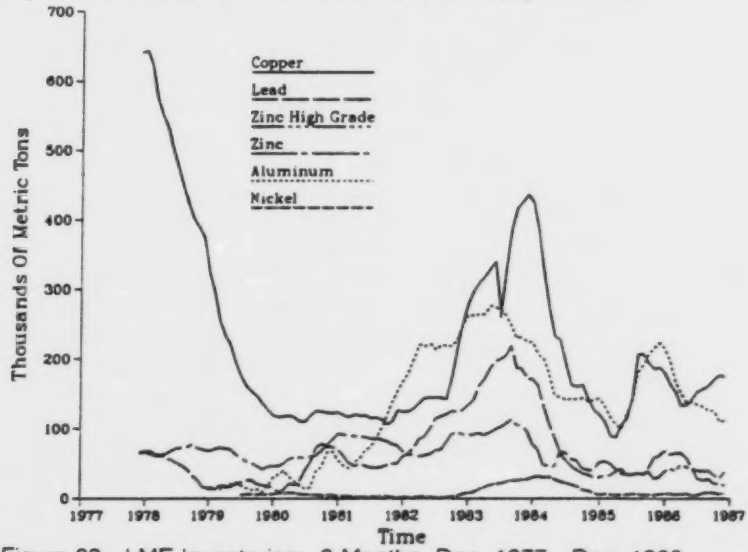

Figure 23. LME Inventories: 3 Months, Dec. 1977 - Dec. 1986

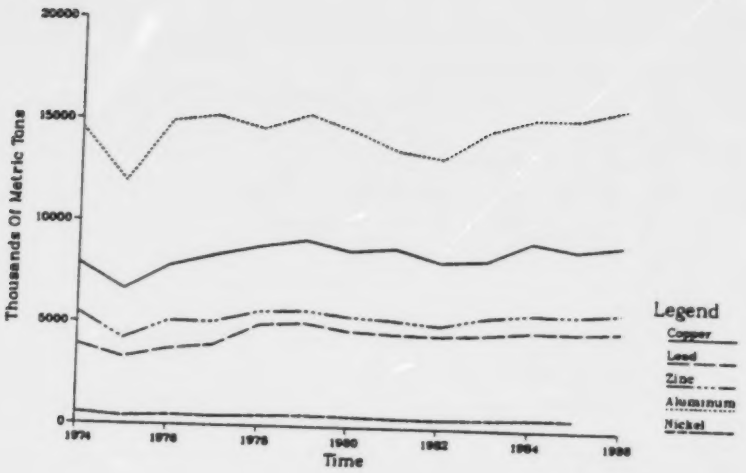

Figure 24. Western World Consumption, Yearly, 1974-86

The tin market was dominated by one large client - the International Tin Council (ITC) - which included both producers and consumers. The ITC was charged with the task of stabilizing tin prices through purchases for and sales from a stockpile. Funds for this project came partially from member contributions. The bulk of the assets, however, were financed through large borrowings from banks and brokers. On 24 October 1985 the ITC ran out of money. Its legacy was a debt of approximately £900 million.

Within minutes of receiving the news, LME transactions in tin were suspended. At the time, the buffer-stock manager had about 120,000 tonnes of tin to price, but the value of these assets would collapse if the tin market were to reopen and the price were allowed to fall. Trading companies worried that if the crisis brought bankruptcies to ring-dealing members with Tin Council contracts, the entire exchange would collapse. Due to the complex financial transactions among brokers, a single bankruptcy could threaten all members of the exchange.

It was clear that many members of the Council did not intend to follow the British government in accepting liability for Council debts.

Banks threatened legal action, claiming that member nations did not have limited liability. At the same time, Council members claimed that an international organization could not be sued.

A compromise plan was worked out. Most consumers supported the scheme but some of the major producers refused to join. The end result was that, in March of 1986, the LME postponed indefinitely any plan to resume trade in tin. Instead they set a fixed price of £6,250 a tonne, well under the minimum price of £8,500 that the ITC had announced it would defend. Exchange authorities immediately faced court action over their decision. The LME, however, defended its action on the grounds that the free fall in tin price that would have accompanied reopening would have destroyed the LME and many of its clients.

The final chapter has not yet been written. A number of companies left the Ring, but a string of bankruptcies was prevented. The total loss will depend on the price at which ITC stocks can be sold over the next few years. What is certain is that the crisis hastened the reorganization of the LME and its change from a principals' market to a clearing house.

The Commodity Exchange of New York

The LME is not without competitors. Principal among these is the Commodity Exchange of New York (Comex), which opened in 1933. Current Comex contracts include copper, silver, gold, and aluminum (although the aluminum contract has not achieved any practical success).

A lengthy discussion of the history and current organization of Comex will not be undertaken. In spite of substantial differences among exchanges, the principal contrast is between exchange and producer pricing. Nevertheless, given that Comex plays an important role in the pricing of some metals (notably copper), it is useful to give a brief summary of the major differences between the LME and Comex. A short list of these differences follows.

1. Unlike the LME, with its strict limitation on seats, membership on Comex is without a formal limit and usually numbers in the hundreds.
2. Traditionally, there has been a higher degree of speculative participation on Comex.

3. The clearing-house system for Comex was established over fifty years ago.
4. The Comex clearing system requires a daily cash settlement in contrast to the prompt or due-date settlement system on the LME.
5. The range of products tenderable against a contract is greater on Comex.
6. Comex offers only monthly contracts and delivery can be made on any day of the month at the discretion of the seller.
7. Trading on Comex can be done as far ahead as 23 months forward, compared to the 15-month forward limit on official LME trading.
8. Until June 1987 there were daily limits on Comex price rises and falls. These limits were imposed to retain control in periods of excess volatility.

Producer Prices

In nonferrous metal industries, many products are produced, each having a separate price. Copper production, for example, starts with ore and goes on to concentrate, blister, and refined copper. But that is not the end. Refined copper goes to the brass and wire mills, foundries, and powder plants. The products of the semifabricators then go to the consuming sectors - the construction, transportation, consumer-product, industrial-machinery, and electronic industries - which in turn fashion new products. At some stages products are sold in a market, whereas at others they are transferred within a vertically-integrated firm. It may therefore seem difficult to say what the producer price of copper or any other metal is.

In spite of this multiplicity of products and prices, there are really only two methods of price determination in these industries: determination by producers and by commodity exchanges.[5] The two mechanisms are very different and result in dissimilar price behavior.

[5] In addition to the two major systems, some commodities are sold on a one-on-one basis. That is, prices are determined through direct negotiations between buyer and seller. These tend to be commodities for which transport costs are a large fraction of total value or which are produced according to customer specification.

Producer prices are those set by the major North American firms in the industry.[6] These prices change only at discrete intervals and have smaller variances than exchange prices. Most often, the producer price is the price of refined ingot. Other products and shapes may sell at premiums and discounts, but their prices will usually be tied to this single price.

The exact method of producer price determination varies among commodities. There are however, broad similarities. The U.S. producer price of copper is therefore discussed in some detail, to give a feel for this general class of pricing. Because the producer price of copper is no longer the predominant copper price, the period of the 1970s is described.

The producer price of copper was that set by the major American and Canadian primary producers and was the price at which most domestic refineries sold copper metal to affiliated and independent fabricators. In the mid 1970s, about 75 percent of refined copper in the USA was sold at this price. The producer price represented a common set of price quotations for delivery of refined copper to any place in the nation. This price was based to a large extent on production cost and was moderately stable.

Some refinery shapes sold at slight discounts and others at premiums, but the prices of all shapes were tied to a single price: the producer price. Copper product prices (the prices of sheet, tube, wire, castings, and so forth) followed the price of refined copper closely. It therefore seems reasonable to speak about the producer price of copper.

Secondary-refined and copper scrap prices, though not determined directly by the metal exchanges, were highly correlated with exchange prices. Scrap, however, traded at a discount, reflecting its lower quality.

Figure 25 shows how the behavior of producer and exchange prices differed in the 1966-76 decade. The U.S. producer price, plotted with a heavy solid line, changed only at discrete intervals. The exchange prices, LME (plotted with a heavy dashed line) and Comex (plotted with a light solid line), changed daily and fluctuated above and below the producer price. It is clear from the figure that the exchange prices were more volatile. Finally, the number two scrap price (plotted with a light dashed line) followed the movements of the exchange prices but at a nearly constant discount.

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[6] The one exception is zinc, which also has a European producer price.

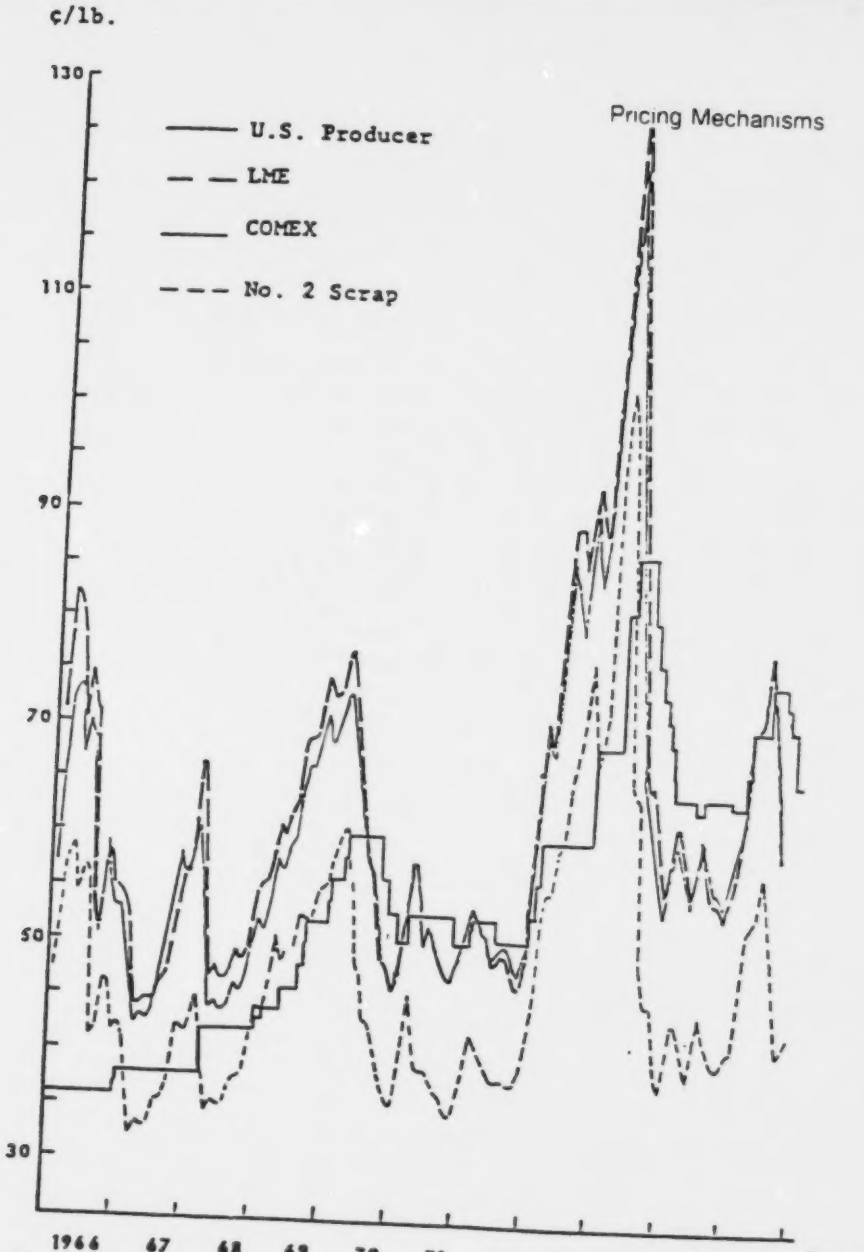

Figure 25. Copper Prices

Source: Metal Statistics, 1977

Relative Merits

Both exchange and producer pricing systems have their virtues and their flaws; this section summarizes the salient pros and cons of each. The discussion, however, should not be interpreted as an attempt to pick a winner or to advise producers which system to use. It should become clear that the choice of system is determined to a large extent by structural conditions within the industry. It should also be clear that there is no single system that works best for all commodities.

A major difference between the two systems relates to the players in the game. Producer prices are determined by producers and, to a lesser extent, by consumers. On commodity exchanges, new actors are introduced: brokers, merchants, and speculators. This introduction has both benefits and costs.

Hedging is one of the benefits. Hedging is defined as the establishment of an opposite position on a futures market from that held and priced in the physical commodity. The practice of hedging, by removing the risk of price fluctuations, provides insurance to both consumers and producers. In fact, the desire to hedge was one of the primary reasons for the founding of the LME and other exchanges.

Speculation can be both a cost and a benefit. In markets that are primarily speculative, prices may bear little relationship to underlying production cost or value in use. This, however, need not be the case. When commodity markets are dominated by legitimate trade, their prices, which are sensitive to supply and demand factors, possess the virtues common to all competitively-determined prices.

A speculator enters a market to realize a profit. This in itself is not a bad thing. And as a consequence, the speculator provides services. In times of surplus, producers and consumers can always find a buyer for unwanted metal, and in times of shortage, they can find someone willing to sell. Rationing, therefore, never exists on commodity markets.

The relationship between speculation and price destabilization is discussed in the next chapter. Here it suffices to note that exchange prices are, in fact, more volatile than producer prices. This can create a problem for producers, who must make production and investment plans, and for consumers, who need to forecast raw material costs. Hedging, which is a partial solution to this problem, cannot provide insurance against very long-run price swings.

The most common complaint about exchanges is that prices are too volatile. Volatility creates problems if unstable prices provide the wrong signals. High prices, for example, may be taken as signals of long-run profitability and may therefore lead to excessive investment in new capacity. Low prices, in contrast, may signal bad times ahead and may discourage exploration more than is warranted by the underlying fundamentals.

Excessive volatility may also cause consumers to substitute away from metals sold on exchanges. If consumers prefer stable prices for planning purposes, and if substitute materials are sold under arrangements that facilitate price stability, metal-conserving technological developments may be triggered in the using sectors.

A significant advantage of exchange-determined prices, however, is their transparency. LME and Comex prices, which are published continuously, have worldwide visibility. In addition, unlike producer prices, they are always true transactions prices and are uniform across customers.

Other advantages include the fact that contracts are never broken.[7] The LME, for example, does not have a *force majeure* clause in its contracts. An exchange therefore provides a dependable contractual arrangement in which everyone can participate at prices that are the same for all. In addition, because rationing is never an issue, customers can purchase all the metal that they want at the going price.[8]

Another useful function of exchanges is their inventory-carrying role. With an exchange system, there is never a need for a potential seller to hold unwanted stocks. And, when excessive inventories cause the contango (the positive difference between the forward and spot prices) to widen, banks can step in. They do this because, by holding inventories, they can earn higher-than-normal returns. The size of the contango therefore does not normally exceed the cost of financing, insuring, and storing metal.

Unfortunately, an exchange pricing system does not ensure against cartel manipulation and prices that are persistently above marginal costs. One need only consider the 1985 tin crisis to conclude that prices determined on exchanges are not synonymous with competitive prices. Nevertheless, it is generally the case that an exchange price

[7] An exception to this statement is when governments fail to honor their obligations, as may have happened with the tin crisis.

[8] When markets are thin, however, a single large purchase can affect price

more closely approximates the competitive norm than does its alternative.

In contrast to exchange prices, producer prices, which are normally based on fundamentals, are relatively stable. Consumers may prefer the security provided by price stability. In addition, by doing away with the need for a broker, a producer price system can foster a bond between buyer and seller.

When the buyer is a vertically integrated subsidiary, the producer can, to some extent, fix the price of the basic raw material used by its downstream operation. In the extreme case of complete vertical integration, there is no useful role for an exchange to play.

Producer prices also facilitate control over market conditions. For example, by setting price below the LME price, producers can clear warehouse inventories. Conversely, by setting price above the LME price, they can provide stability in a falling market.

Control over price can, however, be costly if improperly exercised. For example, most specialists agree that the producer price of nickel was set too high in the late 1970s, a fact which contributed to its own downfall. Prices can also be set too low, as was the case with the Climax price of molybdenum at the turn of the decade. By setting the price too low, AMAX exacerbated the already existing shortage.

When the producer price is the only price and it is suspended, the result is a free-for-all (a situation that occurred in the nickel market in 1977). Markets without well-organized commodity exchanges are therefore more vulnerable to actions by a single firm or small group of firms.

A final disadvantage of producer prices is their lack of transparency. This situation is especially acute when discounting off published prices becomes rife. Under these circumstances, it is impossible to tell what one's competitors are paying for their raw materials.[9]

At this point, it is perhaps helpful to list circumstances that tend to lead to greater reliance on exchange markets. These include:

- an increase in the number of sellers;
- an increase in the number of buyers;
- a fall in vertical integration;
- an increase in government participation;

[9] This is not always a disadvantage. Producers may prefer to price discriminate and consumers may prefer to have their raw material costs remain secret.

- an increase in the geographic integration of markets;
- an increase in product standardization;
- an increase in secondary production.

A glance at these factors should convince the reader that the greater reliance on exchange prices that has characterized the past decade is a symptom more than a cause. As metal markets have become more competitive and more international, the inevitable result has been a weakening of the traditional producer pricing system.

4. FACTORS AFFECTING PRICE STABILITY

Metal markets are well known for their instability. For example, the U.S. Nonfuel Minerals' Policy Review[1] found metal prices to be four times more volatile than prices in the economy as a whole. The instability of these markets has been studied by industry members, consumers, and governments throughout the world. Each of these groups is concerned with the nature and causes of severe price fluctuations and the gluts and shortages that result as a consequence.

There are many reasons why metal prices may be unstable. In the short run, price elasticities of supply and demand are generally low. Short-run supply elasticities are low because mineral industry capacities cannot be varied quickly or at low cost. Demand elasticities are low because mineral commodities are typically used as intermediate inputs, where their cost often constitutes only a small fraction of final-good price. For these reasons, moderate price changes may have little effect on production and consumption in the short run.

Prices are also unstable because income elasticities of demand for metals are generally high. Income elasticities are high because nonfuel minerals are consumed to a large extent for industrial purposes. Changes in economic activity, therefore, may lead to sizeable fluctuations in metal prices.

Finally, prices are volatile because mineral-commodity investment projects are typically large, and because there are often long delays between the initiation and completion of these projects.[2]

This chapter discusses some of the structural and institutional factors that affect the stability of prices.[3] The discussion is general rather than relating to specific commodities. The next chapter, in contrast, describes individual commodity markets.

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1 U.S. Nonfuel Minerals Policy Review Background Papers, (Washington, D.C., U.S. Department of the Interior, 1979).

2 For an analysis of how the nature of mineral-industry investment can cause price cycles, see M.E. Slade, "Cycle in Natural-Resource-Commodity Prices: An Analysis in the Frequency Domain", *Journal of Environmental Economics and Management*, 1982, no. 9, pp. 138-148.

3 For further analysis of metal-price instability, see J.E. Tilton, "Impact of Market Instability for Mineral Materials", *The World Economy*, 1978, no. 1, pp. 369-383.

Primary Market Structure

Primary metal production is production from metal ores. Primary production contrasts with secondary production, which is production from scrap, or recycling. The two most important aspects of the structure of primary markets are horizontal concentration and vertical integration.

Horizontal Concentration

Horizontal market structure refers to the number and size distribution of firms in an industry. For example, an industry with only two firms is said to be more concentrated than one with 100. In addition, a market with one large firm and several small ones is generally considered to be more concentrated than one with the same number of equal-sized firms.

Markets that are concentrated tend to have more stable prices than those with many producers.[4] There are many reasons why this might be so. One of the most important is the availability of instruments to the firms in the market. In a competitive market, firms are price takers. As prices fluctuate, producers can alter the level of their output, but they cannot control price directly. In a concentrated industry, in contrast, firms can choose to vary price, output, inventories, or some combination of the three in response to fluctuations in demand. This higher degree of control usually results in more stable conditions.

When price is to some extent controlled by individual firms, managers must weigh the costs and benefits of changing prices. Economists have focused on two factors that might lead managers of firms in concentrated industries to choose not to adjust prices continuously and fully. Both are related to the costs associated with price changes. The two types of costs are fixed and variable costs.

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[4] C. Nappi, "Pricing Behaviour and Market Power in North-American Nonferrous-Metal Industries", *Resources Policy*, 1985, no. 11, pp. 213-224; D.W. Carlton, "The Rigidly of Prices", *American Economic Review*, 1986, no. 76, pp. 637-658; and S. Domberger, "Relative-Price Variability and Inflation: A Disaggregate Analysis", *Journal of Political Economy*, 1987, no. 95, pp. 547-566.

Fixed costs are costs that are incurred each time a price is changed. Such costs are independent of the size of the change.[5] When, for example, a new price schedule must be printed, a fixed cost is incurred. Alternatively, continuous monitoring of prices may be costly, so that prices are reviewed only periodically. With fixed costs, there is an incentive to adjust prices infrequently but by large amounts.

Variable costs, in contrast, increase with the size of the price change. If it is costly for consumers to stay informed on relative prices of substitute materials, they may prefer frequent, small price changes. Behavior of prices in the nonferrous metal industries more closely resembles the predictions of the fixed-cost models.

Inventories can also play an important role in stabilizing prices in concentrated industries. Newbery notes that dominant firms often hold much larger inventories than their market share would warrant.[6] This behavior can be explained as follows. The benefits of price stabilization accrue to the industry as a whole whereas the costs are private. Price stabilization is therefore to some extent a public good. Only firms with a large share of the market can capture a sufficient share of the benefits to warrant engaging in private stabilizing activities.

Typical examples of competitive markets with unstable prices are agricultural commodities sold on exchanges, such as wheat and other grains. Typical examples of markets with stable prices are metal markets controlled by a single producer, as was the case with molybdenum prior to the 1970s (see figure 4).

Economists have devised several methods of measuring horizontal market structure. The two most common are the N-firm concentration ratio (CR_N) and the Hirschman-Herfindahl index (HHI).

The N-firm concentration ratio is the simpler of the two. It is defined as the output of the N largest firms in the industry divided by total industry output. Formally, this ratio is

$$CR_N = \sum_{i=1}^{N} Q_i / \sum_{i=1}^{T} Q_i \quad (1)$$

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5 G.A. Ackerlof and J.L. Yellen, "A Near-Rational Model of the Business Cycle and Wage and Price Inertia", *Quarterly Journal of Economics*, 1985, no. 100, pp. 823-838; and G. Mankiw, "Small Menu Costs and Large Business Cycles: A Macroeconomic Model of Monopoly", *Quarterly Journal of Economics*, 1985, no. 100, pp. 529-537.

6 D.M. Newbery, "The Manipulation of Futures Markets by a Dominant Producer", in R.W. Anderson (ed.) *The Industrial Organization of Futures Markets*. (Lexington: Lexington Books, 1984).

where Q_i is the output of the i'th firm, T is the total number of firms in the industry, and firms are ordered according to size (with number one the largest). N can be chosen to have any value. Typically, however, the four and eight-firm ratios are considered.

An alternative way to express the N-firm concentration ratio is as

$$CR_N = \sum_{i=1}^{N} S_i \quad (2)$$

where S_i is the i'th firm's market share. Again, the firms are ordered according to size, with number one being the largest.

The N-firm concentration ratio will obviously equal one if there are four or fewer firms in the industry. And, as the total number of firms increases, the ratio approaches zero. One criticism of this ratio is that it is insensitive to the size distribution within N. That is, it will have the same value when there is only one firm, when there are N firms of equal size, and when there is one large firm and N-1 small ones.

The Hirschman-Herfindahl index was designed to overcome this difficulty. The HHI is calculated as the sum over all firms in an industry of their squared market shares. Formally,

$$HHI = \sum_{i=1}^{T} S_i^2 \quad (3)$$

where S_i and T are defined as before.

The HHI also ranges between zero (in perfectly competitive markets) and one (for a monopoly). Its advantage, however, is that it gives relatively more weight to firms with larger market shares.

In chapter 6, both of these measures are calculated for North American markets for the seven commodities of interest. The calculations are performed for the decades of the 1970s and the 1980s.

Vertical Integration

Vertical Integration is present when upstream and downstream operations are performed by the same firm. For example, a mine, smelter, and refinery may be owned and operated by the same company. Mining companies are typically at least partially vertically integrated. The extent of vertical integration in these industries is higher than in the economy as a whole.

The effect of vertical integration on price stability is ambiguous. On the one hand, if all firms are entirely integrated into downstream operations, products transfer within a firm and the market is suppressed. When prices don't exist, there is no possibility of price instability.

A high degree of vertical integration, in contrast, coupled with a small outside market, can lead to excessive price volatility. Under these conditions, when demand is unexpectedly high, there is only a thin market to absorb the shock. Prices may therefore rise to higher levels than they would if the entire output of the industry were sold in a market.

Economists have paid much less attention to devising measures of vertical integration than they have to measures of horizontal concentration. Intuitively, one might calculate the degree of vertical integration as the fraction of total output of upstream operations in an industry that is transferred internally to downstream subsidiaries. This measure, like those defined above, takes on the value of zero when there is no integration and one when vertical integration is complete.

Perhaps one reason for the lack of calculations of measures of vertical integration is the problem of data availability. Standard statistical sources publish mine output by firm but they do not record the fraction of that output that was transferred internally. For this reason, we must resort to qualitative measures such as "high", "medium", and "low". This is the approach taken in chapter 6.

Secondary Markets

In the secondary industries, metal production is from scrap, not ores. There are three types of metal scrap: new, home, and old. New scrap is industrial scrap that is generated at various stages of the production process. Home (or run-around) scrap, a subset of new scrap, is recycled by the same company that generated it. Because home scrap never leaves the company and is never marketed, it is generally not included

in new-scrap statistics. Old scrap, in contrast, is recovered from discarded and worn-out products.

Scrap can be virtually pure metal or it can be one of many alloys, ranging down to very low content of the metal of interest. Refinery slags, skimmings, and ash, though not technically scrap, can also be treated by the secondary industries.

The variety of products processed leads to a wide range of production costs in the secondary industries. Recycling of high grade material can be cheap compared to primary production, but as more refractory products are treated, unit costs increase.[7] For this reason, the secondary producer is often the marginal producer, with little output when prices are low coupled with heavy production when they are high.

The marginal nature of secondary recovery has implications for price stability. When unexpectedly high demand can be partially absorbed by increased recycling, prices do not have to rise as much to clear the market. We therefore expect a large recycling sector to be associated with a greater level of price stability. This may not always be the case. If there is a large recycling sector processing low-cost material, prices may have to fall very far to clear the market in a downturn.

As with vertical integration, there is no standard measure of the importance of secondary markets. Intuitively, however, it can be measured by recycled metal as a fraction of total supply or by recycled metal as a fraction of total demand. In chapter 6, both ratios are calculated for North American markets.

Byproduct Production

Many ores contain more than one metal. Lead and zinc, for example, often occur together, as do copper and molybdenum. Metals produced from the same ores can be considered either coproducts or byproducts. Joint production is labeled coproduction when two metals are of roughly equal importance. When this is the case, joint costs are allocated to the

[7] For empirical evidence of diminishing returns to recycling, see M.E. Slade, "An Econometic Model of the U.S. Secondary Copper Industry: Recycling versus Dispoal". *Journal of Environmental Economics and Management*, 1980, no. 9, pp. 122-137 and *An Econometric Model of U.S. Copper and Aluminum Industries*, (New York: Garland Publishing Inc., 1984).

two in proportion to their respective volumes or price-weighted volumes.[8]

A byproduct, in contrast, is considered to be of only secondary importance. We then have a primary product and a byproduct. When this is the case, joint costs are typically allocated solely to the primary product. This difference in cost allocation implies that byproducts are a cheap source of supply and that, as a consequence, supply is insensitive to price at the low end.

There is a fundamental difference between joint production in most industries and in the mineral industries. Metals occur in a given ore in fixed proportions. The producer can therefore decide to recover or not to recover a byproduct. Continuous substitution in production, however, is often not feasible. Joint production in mining is therefore less flexible than in most manufacturing.

When production occurs in fixed proportions, supply of the byproduct responds to the price of the primary product and not to its own price. For this reason, changes in own price may not play their usual role of signalling the need to change output. Fixed-proportion production, therefore, implies that byproduct supply is insensitive to own price. Just as with the method of joint-cost allocation, the nature of joint production has implications for price stability. We can therefore conclude that prices will be unstable when byproducts constitute a relatively large share of the market.

We run into the same problem in measuring the importance of coproducts and byproducts as with vertical integration. Again there is a natural measure: the fraction of total output that is considered to be a coproduct or byproduct. Again, unfortunately, the data do not exist. Companies may decide internally how to label their products but standard statistical sources do not record these figures. As before, we must therefore resort to qualitative measures such as "high" and "low".

End Use

The structure of demand is also important in determining price stability. Two factors are considered here: the stability of the output of the using

[8] All methods of allocation of common costs are somewhat arbitrary. What I report here is common practice in many of the industries or interest.

sectors, and the ease with which other materials can be substituted for the metal of interest.

If the using sectors are themselves very unstable, derived demand for metal will be unstable as a consequence. For example, if metal were combined with other inputs in fixed proportions to produce a downstream product, fluctuations in metal use would be entirely determined by fluctuations in the output of the using sectors. For this reason, we expect prices to be more volatile when downstream markets are unstable.

Metal, however, is rarely combined with other inputs in fixed proportions. The using industries usually have some degree of flexibility in choosing input ratios. When substitution is easy, a high metal price will trigger a switch to an alternative material. The converse will be true when prices are low.[9] For these reasons, we expect metal prices to be more stable when substitution is easy.

Measurement again presents a problem. In my discussions with commodity specialists, I had them rank metals in terms of both stability of end use and ease of substitution. Unfortunately, end-use stability seemed to be fairly uniform across commodities. For this reason, only ease of substitution is considered in the statistical analysis of chapter 6. And again, only qualitative measures were available.

Exchange Rates

Metals are traded on international markets. Both the dollar price of metals quoted in pounds and the pound price of metals quoted in dollars will fluctuate with changes in the dollar/pound exchange rate, even when the quoted price remains constant. In addition, mining costs are paid in many currencies. As the pound and dollar exchange rates fluctuate with respect to these currencies, we also expect to see changes in metal prices.

Periods of high exchange-rate volatility are therefore expected to be associated with metal price instability, all else being equal: that is, even if there were no inflation in the respective countries, as relative currency values changed, metal prices would change.

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[9] Some specialists claim that substitution away from metals is often irreversible. This should be the case, however, only if the substitute is economically superior. In other cases, substitution should work both ways.

Figure 26 shows the U.S.-dollar exchange rate with respect to four major currencies. Each graph represents the number of U.S. dollars per unit of foreign currency over the 1970-86 period. The solid line refers to the U.K. pound, the dashed line to the Canadian dollar, the dotted line to the Deutschmark, and the alternating solid and dashed line to the Japanese yen. In the figure, all four exchange rates were normalized to equal one in 1979. This was done to facilitate comparisons across currencies.

Figure 26. Monthly normalized exchange rates (1979 = 1), 1970-86 U.S. dollar per foreign currency

The figure shows that there were substantial changes in relative currency values in both the 1970s and the 1980s. In particular, the U.K. pound and Canadian dollar fell with respect to the U.S. dollar over most of the period, whereas the yen and mark rose. It is difficult to tell from the figure, however, which decade is associated with greater exchange-rate volatility.

Table 1 shows descriptive statistics for percent changes in the four exchange rates. For each rate, the mean, variance, minimum value, and maximum value of the percent change in this rate is given for each period. A fifth row is shown for both periods. This row lists the averages of the means, variances, minimums and maximums for each period, where the averages are taken across the four rates.

Table 1

PERCENT CHANGES IN EXCHANGE RATES

Currency	Period	Mean	Variance	Minimum	Maximum
$US/$Can	I	-0.081	0.92	-3.29	4.03
$US/UK	I	-0.178	3.46	-5.39	4.42
$US/DM	I	0.621	5.95	-6.69	9.95
$US/Yen	I	0.567	4.57	-6.42	7.86
Average	I	0.232	3.73	-5.45	6.57
$US/$Can	II	-0.163	0.94	-3.30	2.38
$US/UK	II	-0.336	7.57	-5.62	10.34
$US/DM	II	-0.059	8.73	-6.55	7.14
$US/Yen	II	0.198	9.67	-6.10	9.85
Average	II	-0.090	6.73	-5.39	7.43

The table, in contrast to the figure, shows clearly that exchange-rate volatility was higher in the 1980s. The average variance in the rate of change of exchange rates in the 1970s was 3.73. This should be compared to the average variance in the 1980s of 6.73. All else being equal, therefore, we would expect greater metal-price instability in the 1980s.

Inflation Rates

All else, however, was not equal. We must also consider inflation rates. Many empirical studies have examined the relationship between rates of inflation and relative-price stability.[10] All conclude the same thing: higher rates of inflation are associated with greater relative-price instability.

This conclusion is not very surprising. As the overall price level changes, firms must adjust their prices to reflect changes in input costs. In addition, the nature of adjustment to inflation varies from industry to industry. We would therefore expect both absolute and relative-price volatility to be associated with high inflation rates.

It is beyond the scope of this report to consider inflation rates in all countries that are important for metal-price determination. Instead, U.S. inflation rates are examined. This choice was made because the prices of most of the metals considered here are denominated in U.S. dollars. Differential changes in inflation rates in other countries will therefore influence U.S.-dollar metal prices through the exchange-rate mechanism.

Figure 27 shows monthly U.S.-dollar inflation rates for the 1970-86 period. It is clear from the figure that inflation rates were most volatile in the mid-1970s. This increased volatility is at least partially due to energy and other raw material price shocks.

Table 2 gives summary statistics for U.S. inflation rates in the two decades. The same numbers are calculated as in table 1. This table confirms the fact that inflation rates were more variable in the 1970s. The variance of inflation rates in this period (0.916) is almost three times as large as the variance in the 1980s (0.351).

[10] R.W. Parks, "Inflation and Relative-Price Variability", *Journal of Political Economy*, 1978, no. 86, pp. 79-95; and S. Fischer, "Relative Shocks, Relative-Price Variability, and Inflation", *Brookings Papers on Economic Activity*, 1981, no. 2, pp. 381-431.

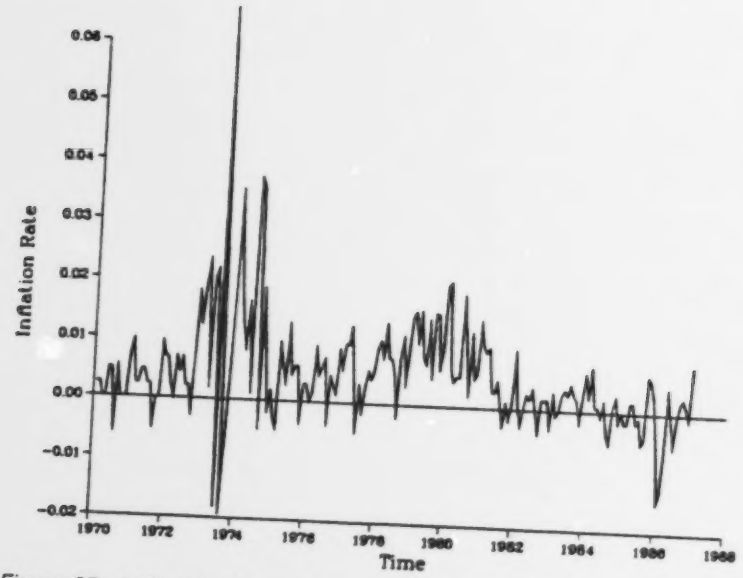

Figure 27. U.S. Inflation Rate, Monthly, 1970-86

Table 2

U.S. INFLATION RATES

	Period	Mean	Variance	Minimum	Maximum
Price Index	I	1.56	0.125	1.08	2.18
Inflation Rate	I	.643	0.916	-1.70	5.65
Price Index	II	2.88	0.066	2.21	3.12
Inflation Rate	II	.423	0.351	-0.552	2.06

We can therefore expect the two effects - exchange and inflation-rate volatility - to offset one another. For this reason, it is not possible to predict a priori what the time-period influence will be in the statistical analysis of chapter 6. That is, higher exchange-rate volatility should lead to more variable metal prices in the 1980s, whereas higher rates of inflation should lead to more variable prices in the 1970s.

Speculation

In chapter 3, we saw how the introduction of commodity exchanges creates scope for speculation. There the emphasis was on the merits of speculation: that is, whether speculation was desirable or not. Here, in contrast, we are concerned with the effects of speculation on price stability.

Do speculators destabilize prices? Perhaps the first to ask this question was Adam Smith.[11] Since that time, many have written on the subject. The conventional wisdom says that speculation stabilizes prices. Speculators, if they are to realize a profit, must buy cheap and sell dear. Low prices should therefore be increased and high prices lowered. It would thus seem that speculation can destabilize prices only if speculators, on average, lose money.

The question, however, is not quite so simple. As Hart and Kreps point out, speculators do not buy when price is low: they buy when the chances of price appreciation are high and sell when the chances are low.[12] These authors build a model of rational agents who possess identical information, and show that it is possible for speculation to destabilize prices and still be profitable.

Others have reached the same conclusion. For example, Hart notes that sophisticated speculators can earn a profit by exploiting the naive forecasting rules of less sophisticated agents.[13] And Newbery demonstrates that if a producer has market power, it may pay the dominant producer to destabilize the spot market by engaging in destabilizing

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[11] A. Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*. Reprint edited by E. Cannan, (New York: Modern Library, 1789-1937).

[12] O.D. Hart and D.M. Kreps, "Price Destabilizing Speculation", *Journal of Political Economy*, 1986, no. 94, pp. 927-952.

[13] O.D. Hart, "On the Profitability of Speculation", *Quarterly Journal of Economics*, 1977, no. 91, pp. 579-597.

speculation, even if all agents are equally rational and have the same information.[14]

Finally, Newbery, like Hart and Kreps, shows that it is not necessary for agents to be unsophisticated or to possess market power for profitable speculation to be destabilizing.[15] Newbery's finding stems from the fact that futures markets, by providing participants with insurance, may encourage them to engage in more risky activities. The net result can therefore be price destabilization.

These theoretical studies demonstrate that speculation can destabilize prices, not that it does. Because the theoretical results are ambiguous in their implications, we should look at empirical evidence. This evidence is summarized by Cox, who concludes that speculation more often than not reduces instability.[16] It remains to be seen what conclusions will be reached in the next chapter, where the determinants of metal-price instability are assessed.

Other Factors

There are numerous other factors that affect commodity price stability. Most of these are difficult to quantify even on a qualitative basis. For this reason, they are not considered in the statistical analysis of chapter 6. Nevertheless, as important determinants, they are clearly worth listing.

In the short run, perhaps the single most important factor is disruption of supply. Disruptions are often due to strikes in the mines, or even to just the threat of strikes. In addition, political difficulties in producer countries and embargoes can be important. Whatever the source, disruptions affect exchange and producer prices alike.

Equally important are changes in mining, smelting, and refining costs. One key change that occurred over the period of this study was the rise and fall of energy prices. Although energy prices are important cost determinants in all extractive industries, the aluminum industry was hardest hit. Aluminum smelting is extremely energy-intensive. As a re-

[14] D.M. Newbury, "The Manipulation of Futures Markets by a Dominant Producer", in R.W. Anderson (ed.) *The Industrial Organization of Futures Markets*, (Lexington: Lexington Books, 1984).

[15] D.M. Newbery, "When Do Futures Destabilize Spot Prices?", *International Economic Review*, 1987, no. 28, pp. 291-297.

[16] C.C. Cox, "Futures Trading and Market Information", *Journal of Political Economy*, 1976, no. 84, pp. 1215-1237

sult, increased energy prices had a profound impact on this industry, particularly in the location of smelters. For example, little aluminum smelting occurs in Japan today. Capacity has shifted to less developed regions such as Brazil that possess cheap sources of hydroelectric power.

Finally, unforeseen events such as wars and depressions can have a major impact. For an example of the effect of a war, see the price of zinc in 1914 (see figure 50 below).

5. THE COMMODITIES

This section looks at each of seven metals in detail.[1] The chosen commodities include the six that currently trade on the LME: aluminum, copper, lead, nickel, silver, and zinc. In addition, molybdenum was selected in order to balance silver, which is not traded on a producer-price basis. Molybdenum, in contrast, is a relatively important metal that is not traded on a metal exchange.

In this part of the report, the factors that were seen to affect price instability in the previous section are considered on a commodity-by-commodity basis. In each case, a short discussion of the history of the metal is followed by an analysis of its horizontal and vertical market structure. Next comes a discussion of the importance of secondary and byproduct production. A description of the consumer side of the market follows and, finally, current pricing practices are explained. Readers who are very familiar with these industries can skip this section without loss of continuity.

For each metal, four graphs are shown. All four pertain to the 1970-86 period. The first is a plot of the principal prices of the commodity in nominal terms. The second shows metal consumption in Canada, North America, and the Western world. In most cases, data pertain to consumption of primary metal. Comparability, however, is limited by data availability. For a more exact description of the data and its sources, the interested reader is referred to the data appendix.

The third and fourth plots show mine and primary production of each commodity on a contained-metal basis. The same three groups are shown on the production side as were considered on the consumption side: Canada, North America, and the Western world. In a few cases, not all of the desired data were available on a consistent basis. When this was the case, that particular series is not shown.

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[1] Most of the material used in this section was gathered through interviews with the commodity specialists whose names are listed in the acknowledgement section. In addition, the publications of the U.S. Bureau of Mines, *Mineral Facts and Problems*, (Washington, D.C.: U.S. Department of the Interior, 1985), proved very useful.

Aluminum

History

Aluminum is the most plentiful metal on earth. It does not, however, occur in native form.[2] Because commercial refining and smelting of aluminum is very energy intensive, it is a relatively modern metal. Aluminum was first isolated in metallic form in 1830, when it was considered a rare and precious substance. Both the Bayer process for refining alumina and the Hall-Herault process for smelting aluminum were discovered in the 1880s. These new technologies made cheap production of the metal possible and were responsible for the rapid growth of aluminum use in the 20th century.

Principal Canadian Company

Alcan

Market Structure

Horizontal Concentration: Still high but falling.

After the breakup of Alcoa's monopoly position in the late 1940s, the industry was dominated by six integrated multinational producers: Alcoa, Kaiser, and Reynolds in the USA; Alcan in Canada; Alusuisse in Switzerland; and Pechiney in France. The major integrated Western companies, however, are no longer so dominant. Entry by Third World producers has caused a decline in concentration, with the result that supply is now less sensitive to price. The six biggest firms currently produce approximately 45 percent of world output, in contrast to approximately 65 percent in the late 1960s.

Vertical Integration: Very high but falling.

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[2] An ore deposit is called native if the metal occurs in elemental or unadulterated form.

Prior to 1973, almost all companies were integrated from mining to refining to smelting, and most were integrated into product markets. The high degree of involvement in the consuming industries distinguishes aluminum from most other nonferrous metals. For example, today Alcoa sells little metal. Many new smelters in Third World countries, however, are not integrated and sell all their metal on the open market.

Recycling: important and growing.

Recycling of aluminum was stimulated by the energy price increases of the early 1970s. Today, the beverage-container sector is the most self-contained of aluminum's markets. This operation is to a large extent handled by the majors. In other uses, market scrap accounts for approximately 20 percent of total consumption.

Importance of Co and Byproducts: very low.

There are no important coproducts or byproducts of aluminum processing.

Use

Principal Uses:

Today, aluminum is the most important nonferrous metal in terms of the volume of consumption. The container and food-packaging sector is the largest of aluminum's markets. This sector has expanded rapidly due to aluminum's light weight and ease of recycling. Aluminum is also used as an electrical conductor in wiring and as a thermal conductor in heat-exchangers. In the 1960s, aluminum's electrical-conductor market grew rapidly. This sector is now stable. In the 1970s, emphasis on weight reduction in the transportation sector contributed to the growth of aluminum use in automobiles, mobile homes, trucks, and trailers. Construction is also a major market.

Ease of Substitution and Conservation: fairly high.

The principal substitute for aluminum in construction is plastic. Carbon and fibre optics have replaced aluminum in many communications and

tensile applications. Aluminum, however, has been a threat to steel and glass in food packaging. It has also made inroads into copper's market in wiring and radiators. Composites can be substitutes for aluminum in transportation.

Pricing

Principal Prices:

Prior to the mid-1970s, the North American producer price was the only important price for the industry. In the second half of the 1970s, however, due to increased entry of nonintegrated smelters mostly in the Third World, the major Western producers began to lose control of pricing in their industry. In October 1978, in spite of strong producer opposition, the first aluminum contract was introduced on the LME. Now the producer price is no longer published and pricing based on LME quotes is common throughout the world. *Metals Week* publishes a price series that is an average of prices used by the principal North American merchants and traders. Realized prices for North American producers, however, tend to be less volatile than either the LME or *Metals Week* published prices.

Discounting:

When the producer price was dominant, there was considerable discounting off list price. Today, however, published LME and *Metals Week* prices and unpublished producer prices are fairly representative of market transactions.

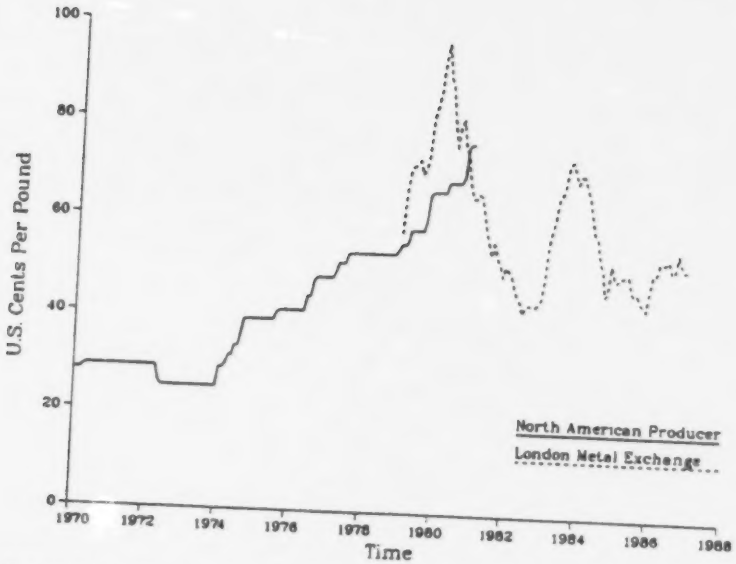

Figure 28. Aluminum prices, monthly, 1970-86

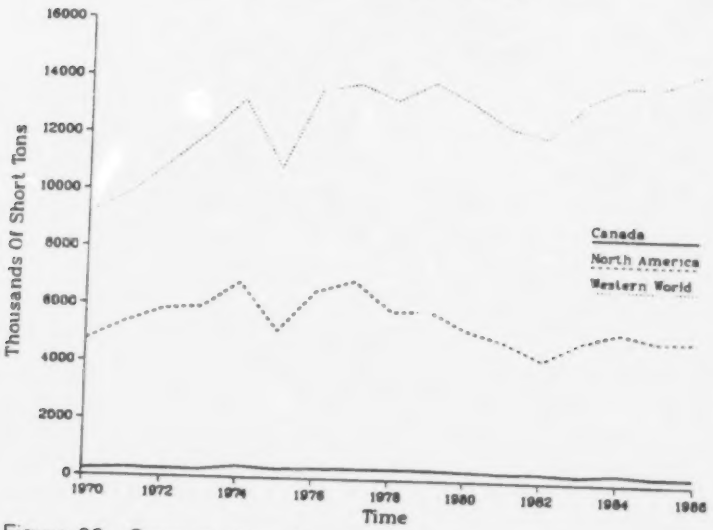

Figure 29. Consumption of primary aluminum, yearly, 1970-86

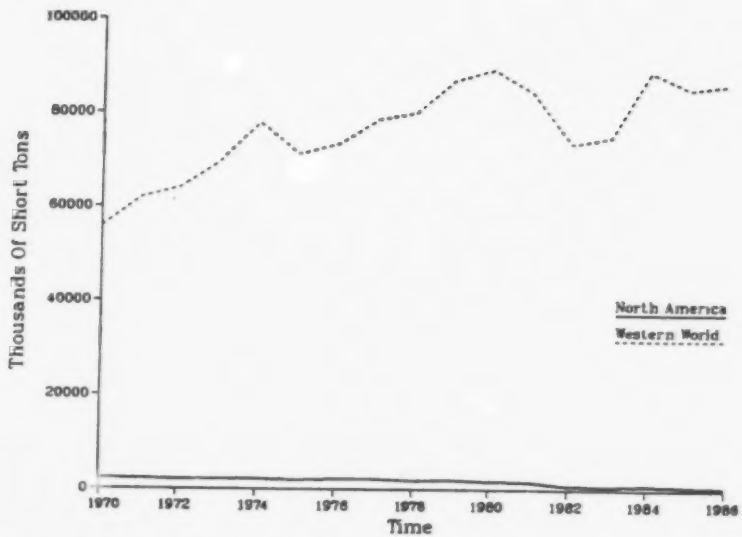

Figure 30. Production of bauxite, yearly, 1970-86

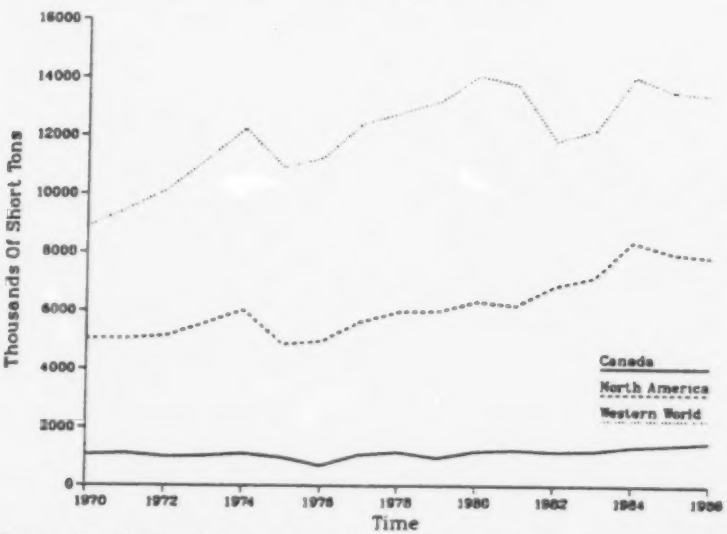

Figure 31. Production of primary aluminum, yearly, 1970-86

Copper

History

Copper, which occurs in native form, was known to primitive man and used for hammered implements. More surprising, however, is the recent discovery of copper smelters in the Timna Valley of the Middle East which date back to 4000 B.C. In this valley, copper was mined, smelted, and formed into a variety of products that were widely traded. The real growth in copper consumption, however, occurred in the 20th century and was primarily due to two factors: first, growth in demand came with the widespread use of electricity; and second, the discovery of froth flotation and the advent of large earth-moving equipment meant that low-grade surface deposits could be mined and processed at low cost.

Principal Canadian Companies

Most major Canadian metal mining companies produce some copper. The largest domestic producers, however, are Noranda, Falconbridge (Kidd Creek), Hudson Bay Mining and Smelting, and Inco.

Market Structure

Horizontal Concentration: moderate to low.

Until the mid-1970s, the industry was dominated by perhaps a dozen major fully integrated producers with mines in North and South America and Africa. Many were U.S. based, such as ASARCO, Anaconda, Kennecott, Cyprus, Newmont, Amax and Phelps Dodge, and others were British and African, including Rio Tinto Zinc, Selection Trust, and the Anglo American interests. Nationalization by Third World governments and entry by Third World suppliers in new areas such as the Philippines and New Guinea, however, has resulted in an industry that is much more fragmented. The net result is that the copper industry has become fairly competitive.

Vertical Integration: moderate and falling.

Traditionally, many copper firms were integrated from mining through end use. Many new Third World producers, however, are much less integrated. In addition, U.S. mining companies have sold off many fabricating facilities. Increasingly, concentrate is sold to smelters in countries other than that of origin. This is especially true in British Columbia, where little smelting is done. Concentrates are sold, mostly to Japan.

Recycling: high.

Copper recycling is very important and becoming more so. Production from old and new scrap constitutes just under half of total supply today. Approximately one half of new scrap is processed internally by mills and the other half is sent elsewhere. Some old scrap is processed by primary producers and accounts for about fifteen percent of refined production. The remainder goes to unaffiliated secondary producers.

Importance of Co and Byproducts: moderate.

The bulk of world copper output comes from mines where copper is the principal metal. Nevertheless, byproduct molybdenum production can be important as can, to a lesser extent, silver and gold. In addition, coproduct zinc-copper and nickel-copper mines are not uncommon.

Use

Principal Uses

Copper is the second most important nonferrous metal in terms of today's volume of consumption. Sixty to 75 percent of the copper consumed today goes into electrical and electronic applications such as motors, generators, power distribution, communications equipment, and house wiring. Copper is also used as a heat exchanger in radiators, heaters, and air conditioners. Other applications for copper and its alloys include roofing, plumbing, machine parts, ordnance, and coinage.

Ease of Substitution and Conservation: high.

Aluminum is copper's only practical substitute in electrical and communications wires and cables. In the 1950s, copper's market for long-

distance transmission lines was eroded. This was followed by microwave towers in the 1960s. Glass fiber communications cables have begun to compete for communications trunklines, and their use is growing rapidly. In heat exchangers, the favored replacements are aluminum and titanium. Aluminum and plastics have replaced copper in many refrigeration and air conditioning applications. In plumbing, plastic is the principal competitor. Finally, copper has many substitutes in machine parts.

Pricing

Principal Prices:

Copper was one of the original commodities traded on the LME. More recently, there were two major pricing systems in the copper industry: exchange-based prices (principally based on the LME) which were used outside of North America, and the North American producer price. In 1973, Cities Service, a relatively small producer, began to quote a Comex-based price. The large American companies, however, held out until 1979, when Kennecott went to a Comex-based price. This marked the virtual demise of the producer price in the copper industry. Today, the LME is the reference price for the world outside of North America, and the Comex price is the North American reference price. Finally, Comex has developed into somewhat more of a speculator's market than has the LME.

Discounting:

Discounting off published prices has never been a major problem in the copper industry. Differences in prices usually reflect differences in quality and in contract terms. Published prices are therefore reasonably good indicators of transactions.

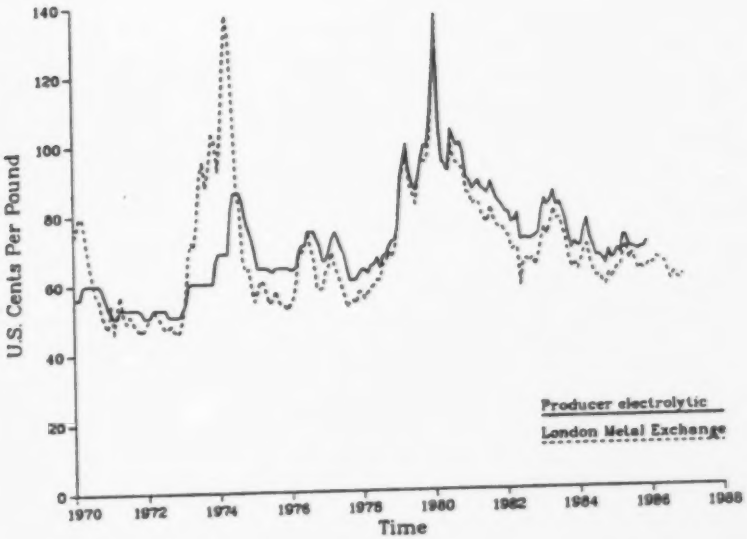

Figure 32. Copper prices, monthly, 1970-86

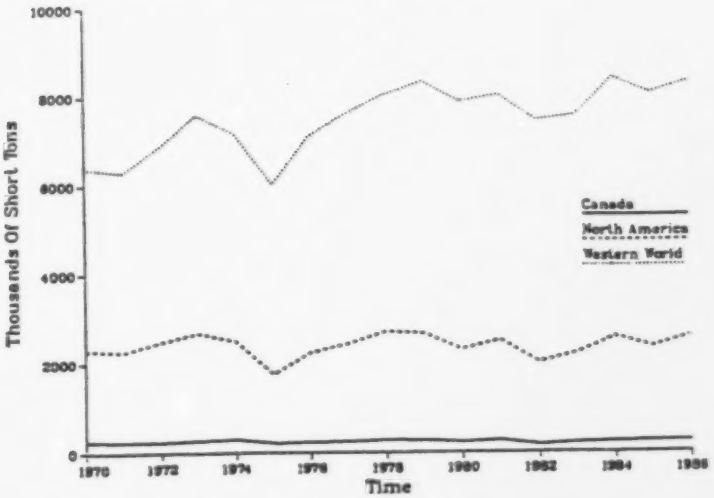

Figure 33. Consumption of copper, yearly, 1970-86

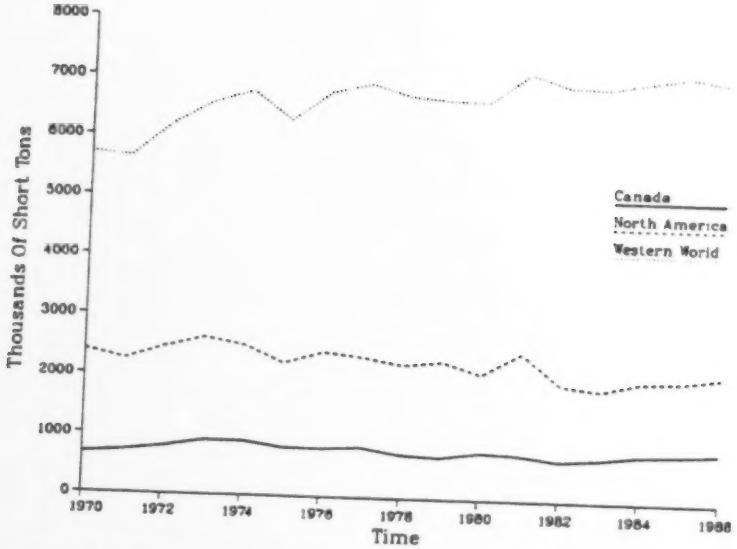

Figure 34. Mine production of copper, yearly, 1970-86

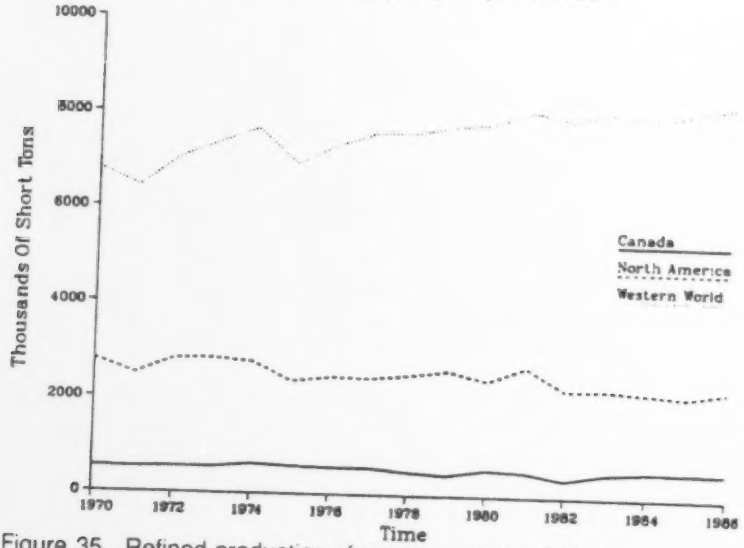

Figure 35. Refined production of copper, yearly, 1970-1986

Lead

History

Like copper and silver, lead has been used for thousands of years. The most important pre-Christian lead mines were located in Spain; British lead production began to be important around the turn of the millennium. In the 20th century, as with other sulfide minerals, the discovery of froth flotation cut milling costs dramatically and caused previously uneconomic deposits to become viable. On the demand side, the most important event was the invention of the electric starting system, which brought lead batteries to vehicles and boosted lead sales. Storage batteries still account for a significant fraction of lead use today.

Principal Canadian Companies

Cominco, Noranda (Brunswick Mining and Smelting), and Curragh.

Market Structure:

Horizontal Concentration: high.

Primary lead production is in the hands of a few large companies which account for approximately 70 percent of world mining. Among these are the Australian companies of Broken Hill, Associated Smelters, and Mount Isa Mines, the U.S. companies of Doe Run and ASARCO, and the major Canadian firms. The industry is particularly concentrated in the U.S. due to the recent merger between two of the three principal firms, St. Joe and Homestake, which became Doe Run.

Vertical Integration: moderate.

Virtually no lead producers are integrated forward into the production of lead products. Approximately 70 percent of world smelter capacity is integrated with local mines. Nevertheless, custom smelters are common in Europe and Japan.

Recycling: very important.

Secondary materials account for somewhat under 50 percent of world output. Most secondary lead is derived from worn-out fabricated products, particularly automobile-starter batteries. Recent environmental regulations in the U.S. declaring lead to be a hazardous waste have accounted for increased recycling costs. Nevertheless, secondary recovery rates continue to be high.

Importance of Co and Byproducts: very high.

Although there are large primary lead mines in the USA, lead and zinc usually occur together. Whether lead is considered to be a coproduct or a byproduct of these mines depends on economic conditions. Today, a combination of low lead prices and a fall in lead demand due to environmental regulations mean that lead is often recovered as a byproduct. Lead recovery in lead-zinc-silver mines is linked to the recovery of silver and is thus relatively insensitive to own price.

Use

Principal Uses:

Between 50 and 60 percent of the lead consumed today is for lead-acid storage batteries. The second largest use is in pigments and other compounds; it is added to paint to produce resistance to corrosion and to glass and ceramics for enhancement purposes. These applications are followed by rolled and extruded products, cable sheathing, and alloys. The use of lead as an octane enhancer in gasoline has fallen dramatically due to environmental regulations. Nevertheless, gasoline additives still account for nearly 5 percent of lead use, principally in underdeveloped countries.

Ease of Substitution and Conservation: moderate.

There are no economic substitutes for lead in batteries. The amount of lead used in an automobile battery, however, has been cut and today's batteries are longer lived. Plastics and stainless steel compete in chemical, construction, and cable-sheathing applications. Substitution away from lead in paint and gasoline is largely due to regulation.

Pricing

Principal Prices:

Dealings on the LME in lead were for many years conducted outside the Ring and on quite a different basis. It was not until 1903 that the first standard lead contract (Good Soft Pig Lead) came into being. Today, the North American producer price is important in North America but elsewhere prices are principally based on LME quotes. The 1980s have been characterized by an increased willingness to adjust producer prices frequently. The producer price is typically about 2.5 cents higher than the LME price. This differential, which varies over time, reflects transport and other costs of transaction between the two regions.

Discounting:

Discounting off list price has rarely been widespread in the lead industry. Price differences usually reflect differences in contractual arrangements.

Figure 36. Lead prices, monthly, 1970-86

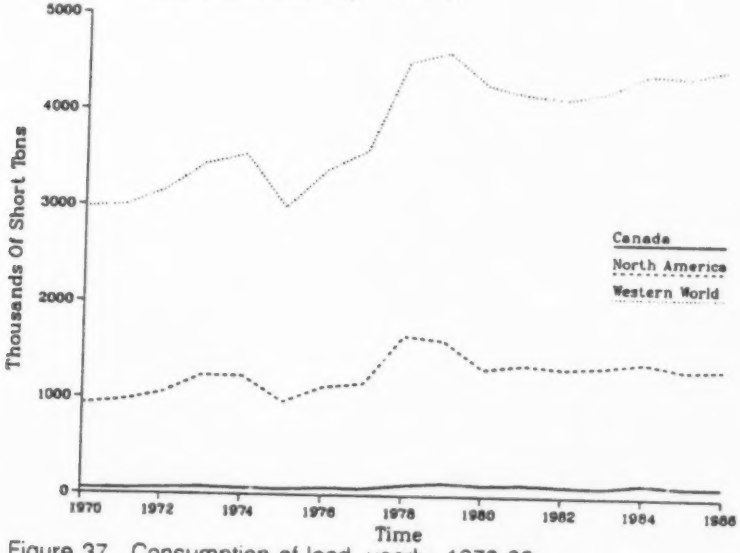

Figure 37. Consumption of lead, yearly, 1970-86

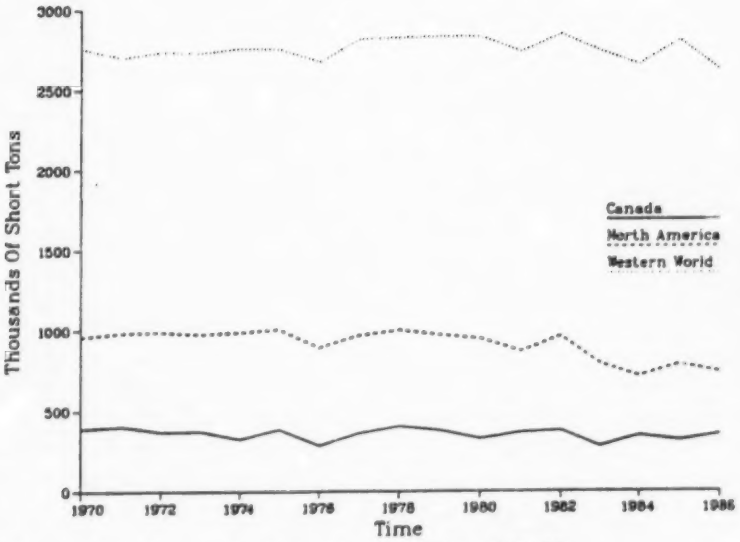

Figure 38. Mine production of lead, yearly, 1970-86

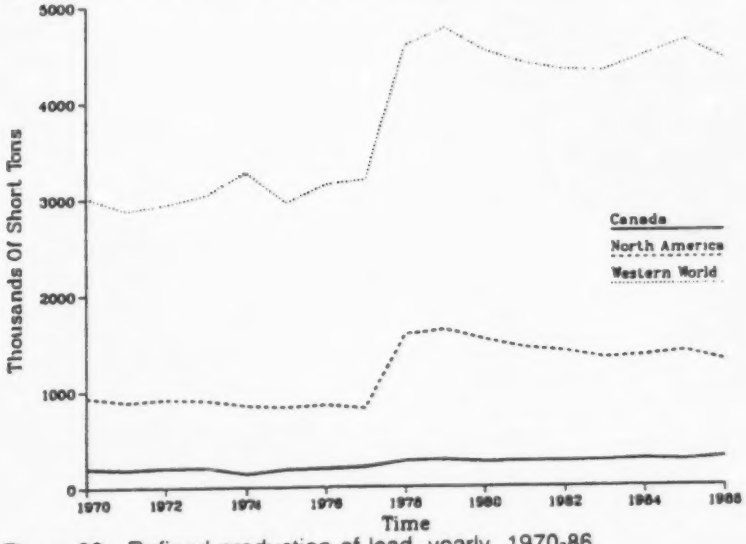

Figure 39. Refined production of lead, yearly, 1970-86

Molybdenum

History

In Greek and Roman civilizations, terms such as molybdos and molybdaena were applied to minerals which were soft and leadlike. It was not until the late 18th century, however, that the Swedish chemist Hjelm produced an impure powder of the metal, which he named molybdenum. The first recorded use of molybdenum as an alloying element in steel occurred in France in 1894, where it appeared in armor plate. World War I generated an appreciable use of molybdenum, when it was substituted for tungsten in high-speed steels. Output was terminated in most countries after the war, however, due to a lack of peacetime applications. Such applications were soon found and the primary mines reopened. The 1930s marked the first recovery of molybdenum as a byproduct of copper mining. Since that time, recovery circuits have been installed in numerous copper-concentrating plants.

Principal Canadian Companies

Placer, Noranda, and Highland Valley

Market Structure

Horizontal Concentration: high but falling.

Historically, the primary molybdenum industry was dominated by a single firm - AMAX - and a single mine - Climax. Today, primary producers include Placer and Cyprus. Large scale entry into primary and byproduct molybdenum production occurred in the 1970s as a result of a tight supply situation and the expectation that the rapid growth rates experienced in the 70s would continue into the next decade. Many actual and proposed projects were subsequently abandoned when continued growth did not materialize. There are more firms engaged in byproduct than primary molybdenum production and byproduct supply is less sensitive to own price.

Vertical Integration: moderate to low.

Although many producers are integrated into roasting, a fair amount of concentrate is sold. In addition, few primary and no byproduct producers are involved farther downstream with the using sectors.

Recycling: moderate to low.

Some pure molybdenum is recovered in the catalyst business. More often, however, molybdenum is reprocessed as a minor constituent of scrap alloy steel. Increasingly, specialty steel companies are buying molybdenum-alloy scrap for recycling purposes. This addition to supply can influence the price at the low end.

Importance of Co and Byproducts: high.

Primary molybdenum mines sometimes process minor byproducts such as tin and tungsten. Much more important, however, is the recovery of molybdenum as a coproduct or byproduct of copper mining. Molybdenum from coproduct and byproduct mines accounts for more than half of world output.

Use

Principal Uses

Molybdenum is used principally as an alloying agent in steel, cast iron, and superalloys to enhance hardenability, strength, toughness, and corrosion resistance. These applications account for over 80 percent of consumption. Molybdenum is also used as a refractory metal, in numerous chemical applications, and as a lubricant.

Ease of Substitution and Conservation: moderate to low.

Vanadium, tungsten, and niobium can be substituted for molybdenum as hardening elements. Due to the high performance and low molybdenum content of steel, however, substitution is not a major problem. In many applications, substitution away from molybdenum will not occur without sizeable relative-price changes.

Pricing

Principal Prices

Until the mid 1970s, molybdenum price was controlled by AMAX and the producer price was the Climax price. In the 1970s, a molybdenum shortage developed due to increased pipeline and related oil-industry demand. A strike at Placer's Endako mine helped fuel the fear of shortage. In the face of increased demand, however, AMAX opted to maintain a low price. Some other producers, in contrast, decided to break away and benefit from the favorable economic conditions. Not all companies, however, were allowed to increase price. For example, the domestic price was already controlled in Canada, and the Canadian government threatened export controls if the domestic oil industry were unable to obtain supplies at low cost. The result was unprecedented: an increase of an order of magnitude in the merchant price, which is known as the dealer oxide price.[3] AMAX no longer publishes a producer price. Unlike the other commodities covered in this report, molybdenum is not traded on an exchange. The volume of sales is insufficient to warrant the introduction of a molybdenum contract on the LME. The only price published today is therefore the dealer oxide price. Although the major producers do not sell at the dealer oxide price, their price quotations are strongly influenced by this price.

Discounting:

When the producer price was the dominant price, discounting was not common. Likewise, the dealer-oxide price that is published today is an estimate of a true transactions price.

[3] The Climax price shown is for a sulfide concentrate. The dealer oxide price, in contrast, is for an oxide product. As can be seen, however, the prices are very similar prior to the enormous run up in price in the late 1970s.

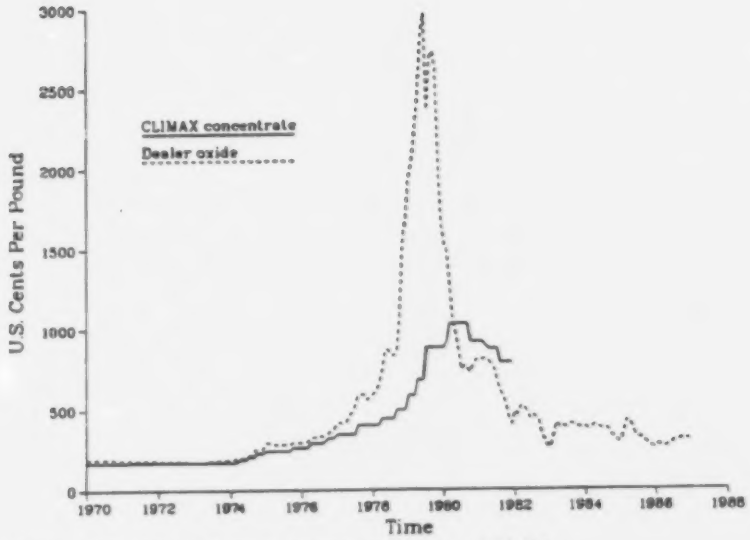

Figure 40. Molybdenum prices, monthly, 1970-86

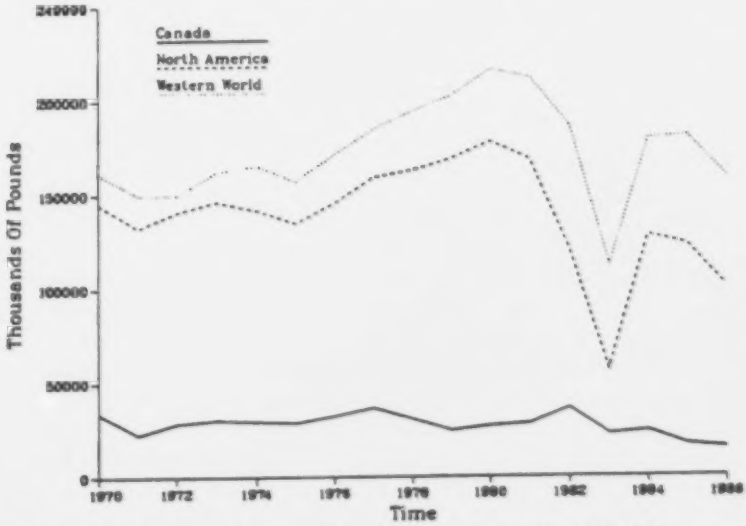

Figure 41. Mine production of molybdenum, yearly, 1970-86

Nickel

History

Meteoritic iron containing 5 to 25 percent nickel was used for axes, knives, and other implements from approximately 4000 B.C. It was not until 1751, however, that Cronstedt discovered the element, which he named nickel after Kupfernickel, the ore in which the element was found. In 1883, copper and nickel were discovered in Sudbury, Ontario. Inco was formed at the turn of the century and dominated mining in this commodity. When nickel supplies were cut off from New Caledonia in 1914, Canada became the only source of nickel supply. Falconbridge was founded in 1928 and flourished under Inco's price umbrella. This umbrella has proven to be very large, and today, Canada's share of world mine production has fallen to less than one third.

Principal Canadian Companies

Inco, Falconbridge, and Sherrit Gordon.

Market Structure

Horizontal Concentration: high but falling.

Inco is the biggest single producing company. The four largest firms in the industry account for more than 50 percent of market-economy metal output. These firms are the Canadian companies Inco and Falconbridge, the French Société Le Nickel, and the Japanese Sumitomo. However, there has been an increase in production in underdeveloped countries, a situation that alters the traditional supply base.

Vertical Integration: moderate.

Most of the large mining companies are integrated into refining. Inco is further integrated into rolling mills. Some ore and matte from New Caledonia, Indonesia, the Philippines, and Australia is shipped to Japan, where the refining companies have no mines. Sherrit Gordon is a custom refiner.

Recycling: moderate.

Scrap is a significant source of nickel supply. The refractory nature of most high-nickel alloys, however, makes processing them to yield separate elements rare. Stainless-steel scrap, for example, is recycled to make stainless steel, nickel-bearing alloy scrap to make nickel-bearing alloys, and nickel-based superalloys to make superalloys.

Importance of Co and Byproducts: high.

Coproduct and byproduct production are extremely important with sulfide ores. For example, on a volume basis (but not on a value basis) more copper is produced in Sudbury than nickel. Gold, silver, and minor metals are also recovered. Many oxide ores contain both nickel and iron. These are processed to yield ferronickel and nickel matte for refining.

Use

Principal Uses:

Nickel's greatest value is in alloys with other elements, where it adds strength and corrosion resistance. Stainless steel accounts for just over half of nickel consumption. High-nickel alloys used, for example, in jet engines and aircraft parts account for another 20 percent. The chemical properties of nickel lead to its use in batteries, dyes (as a catalyst), and in insecticides. Nickel is also used in foundries and coinage.

Ease of Substitution and Conservation: low.

There are few substitutes for nickel in most of its uses, and using substitute materials often requires increased costs or a sacrifice of product performance. However, there are substitutes for many nickel products. For example, the nickel-plated bumper is almost a thing of the past, and ceramics could be substituted for high-nickel alloys in jet engines.

Pricing

Principal Prices:

Traditionally, Inco was the price leader. For decades, the industry was highly profitable and consumption grew at a steady rate of 6.5 percent per year. In the mid 1970s, however, when consumption tailed off the producers did not respond with price cuts. When inventories grew and new producers entered the industry, the market finally collapsed. The producer price was suspended in 1977 due to heavy discounting but was restored in 1978. As nickel was not traded on an exchange at that time, the result was a free-for-all. In spite of producer opposition, a nickel contract was introduced on the LME in April 1979. The producer price survived, however, until 1982. Today, the LME is widely used as the reference price. Nevertheless, the LME nickel market is still thin. Since 1982, LME quotations have been the principal determinants of market transactions. While Inco's realized price does not equal the LME price, the high visibility of the LME nickel contract severely limits the price that the company and other North American producers can obtain for their metal. The difference between realized and LME prices usually reflects transport and other transactions costs and product premiums.

Discounting:

In the days when Inco controlled price, its published price was a true transactions price. Today, discounts and premiums reflect transactions costs and product differences. Other sorts of discounting have never been widespread in this industry.

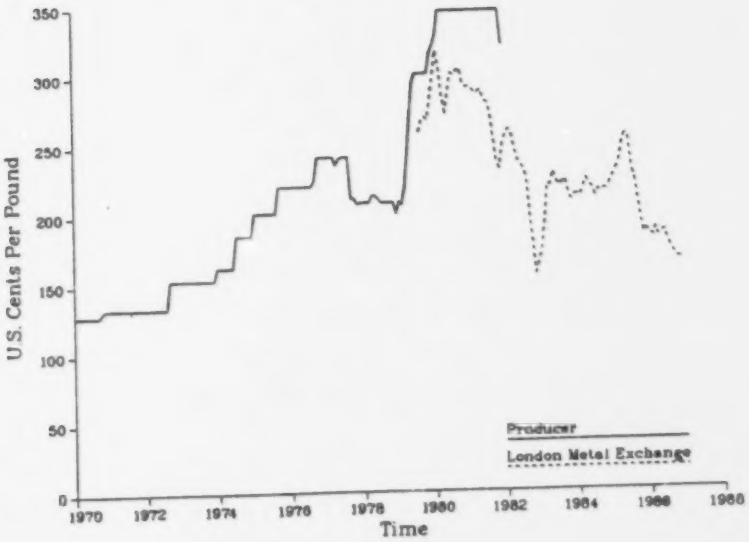

Figure 42. Nickel prices, monthly, 1970-86

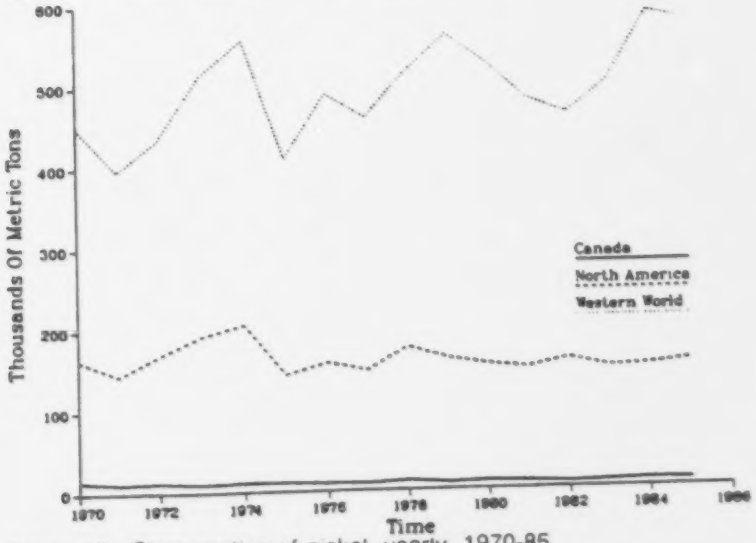

Figure 43. Consumption of nickel, yearly, 1970-85

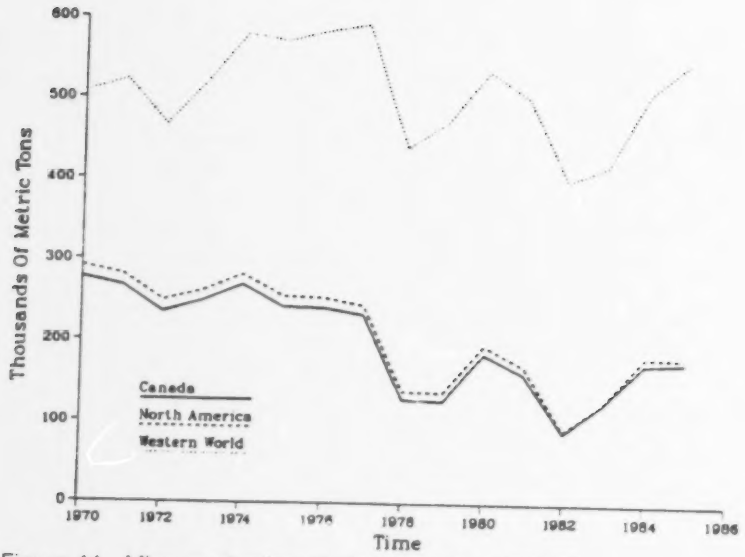

Figure 44. Mine production of nickel, yearly, 1970-85

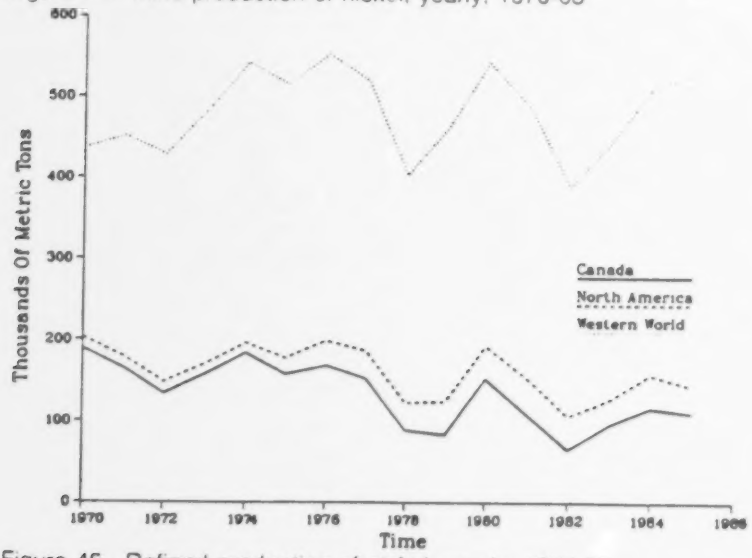

Figure 45. Refined production of nickel, yearly, 1970-85

Silver

History

Like copper and lead, silver has been used for thousands of years. Due to its use as a monetary unit, silver has played a large role in the history and politics of many countries and has triggered very emotional responses. For example, in the USA the Populist movement of the turn of the century denounced the demonetization of silver as a crime that "brought tears to strong men's eyes and hunger and pinching want to widows and orphans". The romance of silver is also illustrated by the many silver "rushes" as, for example, to California's Mother Lode. Today, however, silver is basically a commercial commodity which is used principally for industrial purposes such as photography.

Principal Canadian Companies

Cominco, Falconbridge (Kidd Creek), Noranda (Brunswick Mining and Smelting), and Placer Development (Equity Silver).

Market Structure

Horizontal Concentration: low.

Silver is mined by many companies in Canada, the USA, Mexico, Peru, Australia, and other countries, usually as a byproduct of other metals. In each of these countries, there are four to six major mining firms. The silver market is therefore relatively competitive.

Vertical Integration: moderate.

Most of the major mining companies are integrated forward into smelting and refining. Few, however, are further integrated into silver products. Some silver contained in base metal (coproduct and byproduct) is sold on the open market.

Recycling: high.

Silver recovered from old and new scrap is an important component of world supply. Old scrap consists of used products such as jewelry, electronic components, photographic materials, batteries, plating solutions, sterlingware and coins. Hoarding by nonproducers has always been an important factor in this market. Secondary silver holders can be either a source of supply or of demand, depending on price expectations.

Importance of Co and Byproducts: high.

Most silver is produced as a byproduct at copper, lead, and zinc mines, although Canada, Mexico, and the USA have significant primary deposits.

Use

Principal Uses:

Silver is rapidly becoming mainly an industrial commodity. The most important use of silver is in photographic materials. Silver is also used in electrical and electronic products because of its high electrical and thermal conductivity and resistance to corrosion. The use of silver for decorative purposes can be divided into three main applications: jewelry, sterlingware, and silver plate.

Ease of Substitution and Conservation: moderate.

There is no direct substitute for silver in photographic materials, but film can be made without silver. Stainless steel is an alternative to silver in the manufacture of table flatware, and gold or the platinum-group metals can be used as a replacement in electrical and electronic applications.

Pricing

Principal Prices:

Silver dealings on the LME have a curious history. Silver was first introduced in 1897, but this contract lapsed in 1911 through lack of interest. A contract was again introduced in 1935, which lasted until the outbreak

of the war in 1939. The final reintroduction of silver trading, in contracts of 10,000 troy onces, occurred in February, 1968. Today, silver is traded on both the LME and Comex but, since the collapse of the silver market due to speculation in the early 1980s, trading on these markets has been thin (see the section on recent crises, p. 23). The most important silver market is the London bullion market, a physical market. The Handy and Harmon price is the North American equivalent to the London bullion price. There has never been an equivalent to a producer price for silver.

Discounting:

There is virtually no discounting off published silver prices.

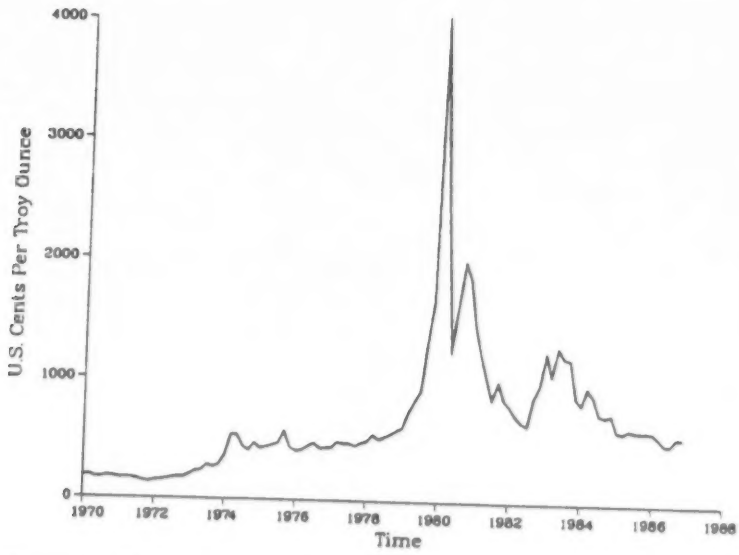

Figure 46. Silver price, montly, 1970-86, LME

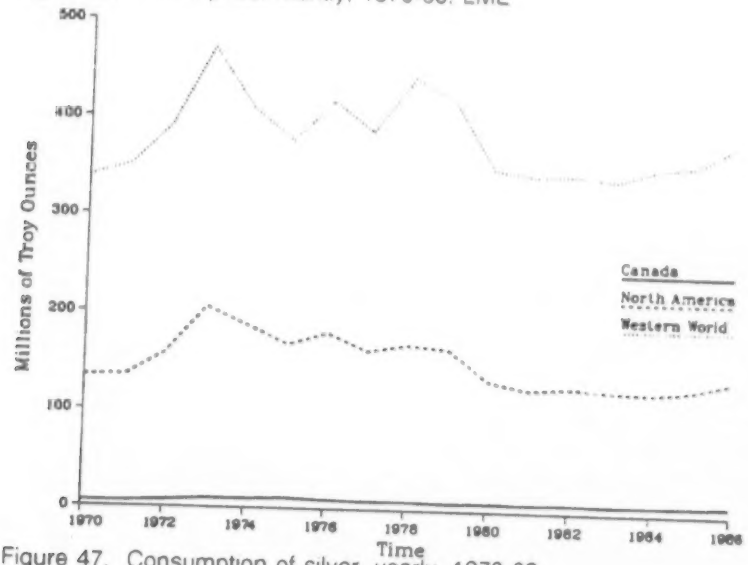

Figure 47. Consumption of silver, yearly, 1970-86

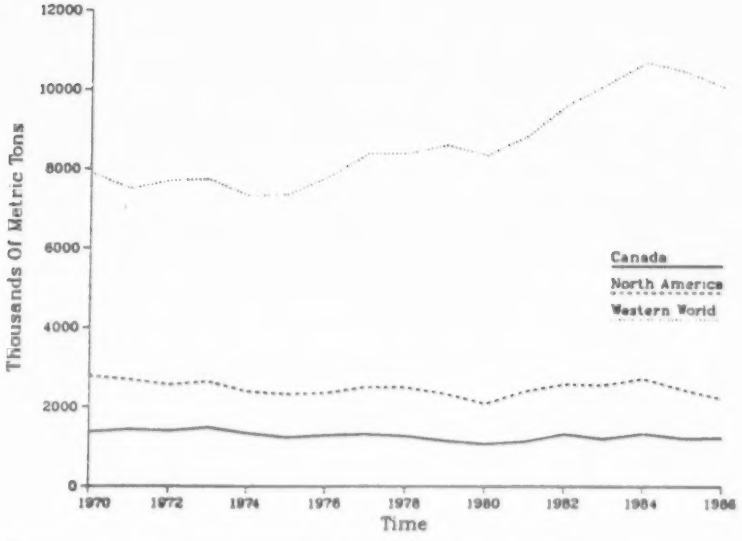

Figure 48. Mine production of silver, yearly, 1970-86

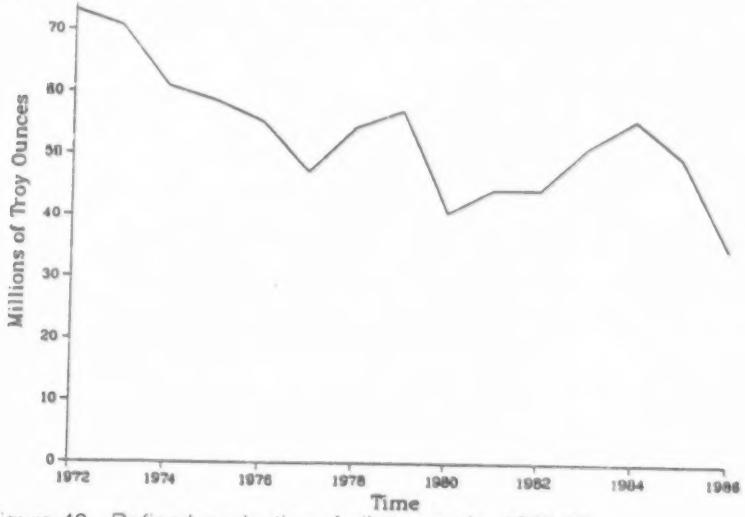

Figure 49. Refined production of silver, yearly, 1972-86
North America

Zinc

History

The history of zinc parallels that of lead. Like lead, it is a metal that has been used for a very long time. In the 20th century, two important factors led to increased production and consumption. On the supply side, the advent of froth flotation lowered costs, and on the demand side, the invention of galvanizing increased use. There is one outstanding anomaly in the history of zinc pricing. Prior to the first world war, Germany mined over 25 percent of the world's zinc ore and refined considerably more. The war cut off this source to Germany's opponents. Zinc, which was used in brass and galvanizing, was badly needed for ammunition and rust proofing. As a result, its price tripled in just one year. This stimulated refinery construction in many industrial countries. When the war was over, the increased supply coupled with a fall in consumption resulted in real prices that were considerably below prewar levels.

Principal Canadian Companies

Noranda, Cominco, Falconbridge (Kidd Creek), and Hudson Bay.

Market Structure

Horizontal Concentration: high and increasing.

The top ten mining companies control over forty percent of the Western world's zinc-mining capacity. Among these are the Canadian firms Cominco, Noranda, and Kidd Creek, the Australian firms Mount Isa Mining and Australian Mining and Smelting, and the Peruvian Centromin. Worldwide concentration at the level of slab zinc production is still higher. Increases in concentration have occurred both through mergers among competitors and through smelter closings due to an inability to meet environmental standards, particularly in the USA. The high level of concentration in the primary industry, coupled with the lack of importance of the secondary industry, means that the market is a tight oligopoly. In addition, unlike the situation with the other nonferrous metals, the trend in worldwide zinc concentration is positive.

Vertical Integration: low to moderate.

Canada and Australia are the two largest Western-world mine producers. Of the concentrates produced by the mines of these countries, approximately half is exported. In addition, few mining companies are integrated into the zinc-consuming industries. In spite of the fact that most of the major mining firms are at least partially integrated into smelting, the custom smelter plays an important role in this industry, particularly in Europe. Some of these custom smelters are integrated into semifabrication.

Recycling: low.

Recovery of zinc from old scrap represents about 8 percent of total supply. The large use of zinc in galvanizing and in compounds in which the zinc is lost limits the potential for increased recycling. New scrap is principally zinc alloy and brass from manufacturing operations.

Importance of Co and Byproducts: high.

Lead and zinc usually occur together. Whether lead is considered a coproduct or byproduct of these mines depends on economic conditions. Today, a combination of low lead prices and a fall in lead demand mean that lead is often considered a byproduct. In addition, considerable quantities of copper, gold, silver, and cadmium are recovered in the mining of zinc.

Use

Principal Uses:

Zinc is the third most important nonferrous metal, after aluminum and copper, in terms of tonnage. Approximately 85 percent of consumption enters the steel, automobile, and construction industries. Galvanizing accounts for about half of its use, followed by diecasting and brass. Zinc oxide is used in rubber, paint, paper, and medical applications. Finally, rolled zinc is used as a roofing and siding material and for battery casings.

Ease of Substitution and Conservation: moderate.

Zinc has maintained its competitive position with substitute materials in most uses. The principal substitutes for zinc in diecasting are aluminum, magnesium, and plastics. This area has suffered the most from substitution, but new alloys for diecasting and corrosion applications will help secure markets from further erosion. There is no substitute for galvanizing in large tonnage applications in iron and steel products. Nevertheless, the electrogalvanizing process has reduced the quantity of zinc needed per unit of output. Aluminum sheet, plastic, and painted steel competes with galvanized steel sheet in roofing and siding. Finally, the competition of alternate materials is significant in chemical and pigment applications.

Pricing

Principal Prices:

Zinc, which was known as spelter until after the first world war, was introduced to the LME in 1915. Today, although the LME price covers less than 5 percent of the world market for zinc, it exerts a strong influence on producer prices. Unlike the other nonferrous metals, there are two important producer prices for zinc: the North American and the European producer price (EPP). The EPP is used by Western producers outside of North America. The price in North America is on average approximately 3 cents per pound above the EPP, reflecting the differential in transport and other transactions costs.

Discounting: moderate.

In recent years, there has been a rise in individually-negotiated prices with consumers so that published producer prices are now not fully representative of market conditions.

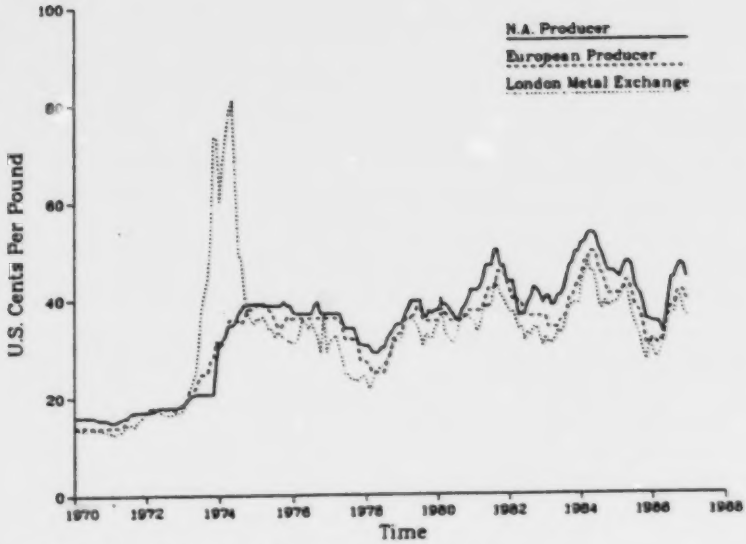

Figure 50. Zinc prices, monthly, 1970-86

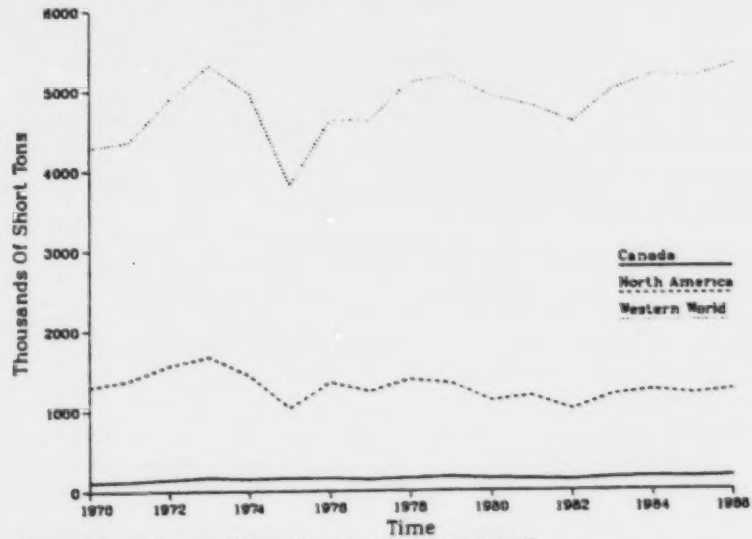

Figure 51. Consumption of zinc, yearly, 1970-86

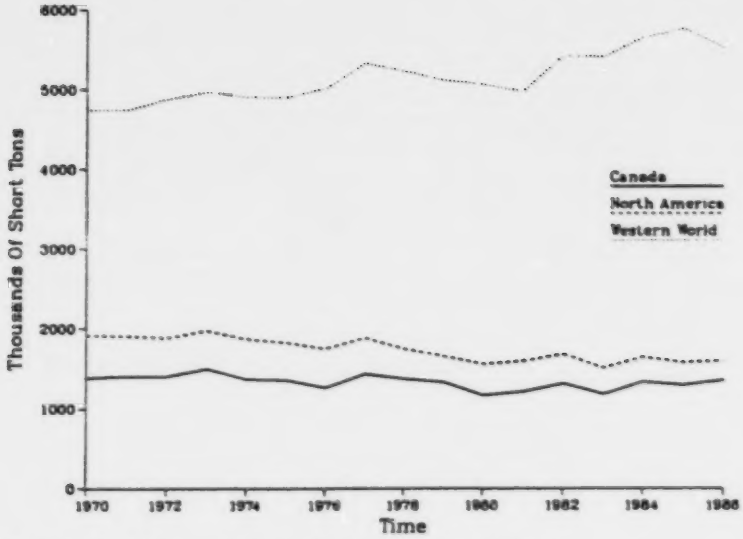

Figure 52. Mine production of zinc, yearly, 1970-86

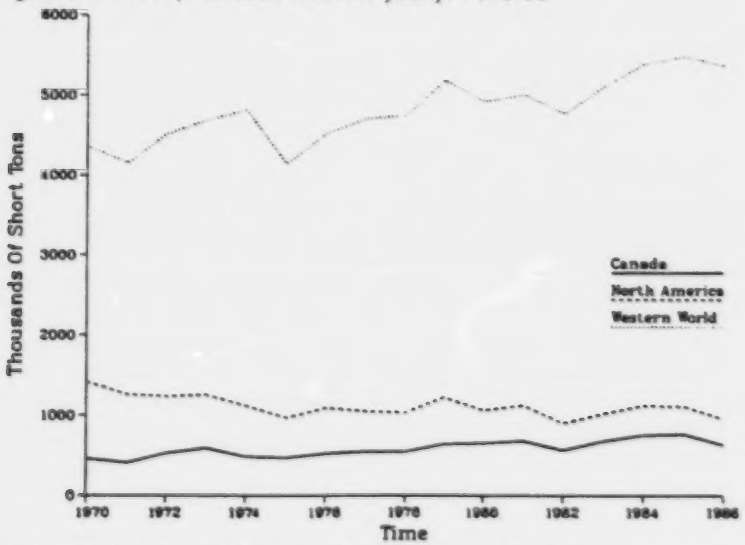

Figure 53. Smelter production of zinc, yearly, 1970-86

6. STATISTICAL ANALYSIS

Chapter 4 contains an informal analysis of the factors that lead to metal-price instability and chapter 5 discusses the importance of these factors for particular commodity markets. Here, in contrast, we wish to assess the importance of the same factors more rigorously. We therefore resort to statistical analysis.

The statistical analysis pertains to the 1970-86 period. The choice of starting period (January 1970) was somewhat arbitrary: the choice of ending period (December 1986), however, was dictated by data availability. The 17-year period is split into two sections - the 1970s and the 1980s. Several important events occurred at the turn of the decade. These include the introduction of aluminum and nickel contracts on the LME and the silver-market bubble. It was therefore considered of interest to test if the two periods are noticeably different and, if so, if the difference can be explained by changes in underlying economic factors.

Preliminary Analysis

Our first task is to determine the stylized facts. That is, we wish to examine the behavior of metal price levels and rates of change in order to see if regular patterns emerge. When this has been done, an attempt will be made to explain these patterns.

Table 3 contains summary statistics for metal price levels. In the table, periods I and II denote the 1970-79 and 1980-86 time periods, respectively. The raw data are monthly nominal prices for each commodity. With two exceptions, the price series shown are those mentioned as being important in the commodity market analysis of chapter 5. For example, for copper we see the producer and LME prices in the first decade and the LME price alone in the second decade.

Table 3

SUMMARY STATISTICS FOR PRICE LEVELS

Price	Period	Mean	Variance	Minimum	Maximum
Aluminum					
Producer[a]	I	39.4	79.8	24.4	53.9
Producer[a]	II	58.8	94.1	44.1	82.0
LME	II	59.6	176.5	41.7	96.6
Copper					
Producer	I	62.9	76.4	50.4	86.3
LME	I	64.1	327.6	45.6	137.6
LME	II	74.5	203.1	57.7	132.4
Lead					
Producer	I	21.4	47.9	13.5	38.0
LME	I	20.3	48.6	10.0	38.9
Producer	II	30.7	140.6	17.7	61.1
LME	II	28.6	167.9	16.0	62.6
Molybdenum					
Climax	I	25.0	96.3	17.2	50.0
Dealer oxide	I	33.6	695.8	17.0	169.0
Dealer oxide	II	72.7	4741.4	25.7	296.8
Nickel					
Producer	I	183.5	1933.4	128.0	300.0
LME	II	232.0	1764.4	155.8	316.6
Silver					
LME	I	34.7	223.9	13.1	59.3
LME	II	101.8	3247.6	50.2	392.5
Zinc					
NA producer	I	27.7	88.1	15.0	39.7
EU producer	I	26.7	80.1	13.8	39.5
LME	I	29.0	239.1	12.4	80.6
NA producer	II	42.1	25.3	33.1	53.4
EU producer	II	38.5	18.2	30.4	49.4
LME	II	35.8	18.2	27.1	47.2

[a] the estimated producer price, not the list price (see pp. 86-87).

The first exception is silver. It was noted that the LME is not an important market for silver.[1] The London bullion-market price is considered to be the reference price. Nevertheless, the LME price is used here because all of the other exchange-based prices are LME prices. In addition, arbitrage across markets causes the two silver prices to be virtually identical.

The second exception creates more serious difficulties. As was noted earlier, there has always been substantial discounting off the published producer price of aluminium. It therefore cannot be considered a true transactions price. The following procedure was adopted to overcome this difficulty.

Metals Week publishes both monthly and yearly-average prices for aluminum. These prices, which are estimates of the prices at which merchants and traders sell aluminum ingot, constitute the first part of the data required to construct a producer price for aluminum which is representative of the realized price of the major firms in the industry.

Alcan's annual reports give figures for annual ingot sales and ingot revenues. An estimate of Alcan's average realized ingot price can thus be obtained by dividing ingot revenues by sales. This is the second part of the data needed to construct a "producer" price.

Seventeen yearly observations on the two prices (1970-86) were then used in a regression analysis. That is, an equation of the form

$$p^A_t = a + bp^{MW}_t + cp^{MW}_{t-1} + u_t \quad (4)$$

was fitted to the data, where p^A_t is Alcan's realized price in year t; p^{MW}_t is the *Metals Week* published price in year t; a, b, and c are coefficients to be estimated; and u_t is a random error term.

The fitted equation 4 was then used for interpolation purposes. That is, we need an estimate of Alcan's realized price in each month. This estimate was constructed from the equation

$$\tilde{p}^A_t = 7.0 + 0.55P^{MW}_t + 0.30P^{MW}_{t-1} \quad (5)$$

In equation 5, $\tilde{p}^A_t$ is our estimate of a realized "producer" price of aluminum. Notice that t now refers to the t'th month.[2] This "producer" price is less volatile than the *Metals Week* price. That is, it is smoother

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1 The LME is also not an important market for zinc. Zinc, however, in contrast to silver, has no important exchange-based price. The LME zinc price is included as the best representative of a terminal price for zinc.

2 The numbers shown in equation 5 are not estimates of b and c in equation 4. The estimate of b was 0.85 and that of c was statistically indistinguishable from zero. In equation 5, the estimate of b is "distributed" over

and has lower peaks and higher troughs. In addition, it lags somewhat behind the *Metals Week* price.

Statistics for the producer price of aluminum shown in table 3 and in the analysis that follows refer to this estimated realized price and not to the published producer price.

Discounting off published zinc-producer prices has also become common in the last three or four years. It was not possible, however, to estimate a realized producer price for zinc. The greater number of Canadian companies involved, coupled with substantial changes in product mix from year to year, rendered all efforts to estimate such a price futile. It was therefore decided to use the published prices, even though they are no longer representative of market transactions.[3]

As in tables 1 and 2, the summary statistics in table 3 consist of mean, variance, minimum value, and maximum value. These are listed for the level of each price series in each time period. Table 4 shows the same summary statistics for the rates of change of prices.

An examination of table 3 reveals little difference in the level of prices determined under the two systems. It is possible, however, to subject this hypothesis to a statistical test. In the table there are six cases where both a producer and an LME price coexist in a given decade.[4] The average of the six producer prices is 40.6 cents per pound whereas the average of the six exchange prices is 39.6. Using the Wilcoxin signed rank nonparametric test for a difference in the means of two paired samples, we cannot reject the hypothesis that pricing system has no effect on price level.[5]

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two months because producer prices for all other commodities lag behind LME prices.

[3] The estimated aluminum producer price is probably more volatile than realized prices, due to changes in product mix. In contrast, the published zinc price is probably less volatile than realized prices, due to discounting. It is hoped that the two effects at least partially cancel each other.

[4] The six cases are aluminum II, copper I, lead I and II, and zinc I and II. Molybdenum is not considered because the two prices are for different products (see page 67).

[5] For a description of this test and those that follow, see J.D. Gibbons, *Nonparametric Methods for Quantitative Analysis*, New York: Holt, Rinehart, and Winston, 1976. An advantage of nonparametric tests is that is that their validity is independent of the underlying distribution of the two populations from which the observations are drawn.

Table 4

SUMMARY STATISTICS FOR RATES OF CHANGE OF PRICES

Price	Period	Mean	Variance	Minimum	Maximum
Aluminum					
Producer[a]	I	0.906	7.8	-9.2	7.4
Producer[a]	II	-0.061	14.4	-7.4	9.6
LME	II	-0.115	24.8	-11.8	13.3
Copper					
Producer	I	0.233	11.9	-6.8	16.7
LME	I	-0.055	54.1	-24.0	19.4
LME	II	-0.144	31.8	-23.5	16.1
Lead					
Producer	I	0.780	12.8	-20.6	9.6
LME	I	0.909	49.0	-17.8	24.2
Producer	II	-0.293	54.4	-20.1	15.7
LME	II	-0.527	43.0	-21.2	14.4
Molybdenum					
Climax	I	0.997	8.6	0.0	15.0
Dealer oxide	I	2.030	29.4	-5.7	34.9
Dealer oxide	II	-1.780	86.8	-25.3	25.0
Nickel					
Producer	I	0.741	9.9	-13.3	14.0
LME	II	-0.530	19.8	-13.9	13.3
Silver					
LME	I	1 804	50.5	-27.4	37.8
LME	II	-0.105	199.5	-49.9	65.1
Zinc					
NA producer	I	0.725	13.2	-6.9	28.6
EU producer	I	0.800	12.9	-14.9	11.7
LME	I	0.767	71.9	-25.1	33.0
NA producer	II	0.246	15.7	-9.7	11.8
EU producer	II	0.197	13.5	-11.5	10.5
LME	II	0.156	30.0	-15.8	13.7

[a] the estimated producer price, not the list price (see pp. 86-87).

Casual observation might lead the reader to draw two additional conclusions from the tables. First, producer prices are, on average, more stable than exchange prices. Second, both sets of prices were, on average, more volatile in the second time period. These observations seem to be true of the variability of both levels and rates of change of prices, as witnessed by the higher variances.

It is again possible to subject these conjectures to more rigorous analysis. That is, we can test these hypotheses statistically. To do this, the Mann-Whitney-Wilcoxin (MWW) nonparametric test for a significant difference in means of two independent samples is calculated.[6]

Table 5 gives sample averages and test statistics for the two periods. The test is for a difference in the average of the variances of the rates of change of prices (VRCP), where the averages are taken across time periods and across pricing systems.

To see how to interpret this table, consider the test by time period. The first number (27.7) is the average of the period I variances found in table 4, the second number (48.6) is the average of the period II variances in table 4, and the fourth number is the value of the MWW test statistic. Finally, the number denoted "P value" indicates that the probability of observing a value of the MWW test statistic that is as large as 1.69, if in fact there were no difference in price variability in the two time periods, is 0.045. Alternatively, we can (somewhat loosely) conclude that the probability that price variability was higher in the second period is 0.965.

The second half of table 5 refers to differences in the variability of prices across the two categories, producer and exchange. In this calculation and those that follow, the dealer oxide price of molybdenum is considered to be an exchange price, even though it is not determined on a commodity exchange. This assumption is made because the dealer oxide price is competitively determined and not set by producers.

Table 5 shows that the chance of observing such a large value of the MWW test statistic for pricing system, if in fact the two systems resulted in equally variable prices, is even smaller than that found for time periods. A P value of 0.0002 indicates that the probability that producer prices are more stable than exchange prices is 0.9998.

[6] Here the averages being tested are the average variances not the average levels.

Table 5

TESTS FOR DIFFERENCE IN MEAN IN THE VARIANCE OF THE RATE OF CHANGE OF PRICES

By Period:	
Average Value of VRCP:	
Period I (1970-79)	27.7
Period II (1980-86)	48.6
Test Statistic	1.69a
P Value	.045
By Pricing Mechanism:	
Average Value of VRCP:	
Producer	15.9
Exchange	57.6
Test Statistic	3.69b
P Value	.0002

The Mann-Whitney-Wilcoxin nonparametric test for a difference in mean is used.
a denotes significance at the 95% level of confidence.
b denotes significance at the 99% level of confidence.

Both conjectures are thus verified. We do not know, however, what caused the differences in variability. For example, it is possible that the difference in marketing systems is responsible for the observed difference in average variance that the second half of table 5 confirms. On the other hand, it is also possible that changes in the underlying structural variables which were discussed in chapter 4 are responsible for this difference, and that the correlation between pricing system and price instability is spurious.

We will therefore consider the statistical relationship between price variability and the market-structure and organization variables of chapter 4. Before doing this, however, it seems important to answer one more question.

A priori, the relationship between price variability and output variability is ambiguous. On the one hand, if producers can substitute between changes in price and changes in production when they adjust to changed demand conditions, we expect to see a negative correlation between price and output variability. On the other hand, if price instability

leads to investment cycles that increase output instability, we expect to see a positive correlation between price and output variability.

To see which effect is more important in the nonferrous metal industries, the variance of percent changes in mine output was calculated for each of the seven commodities for the 1970-86 period. Output variability was then compared to price variability for the same commodities.[7] The Spearman rank correlation coefficient, which tests the degree of (positive or negative) association between two paired samples, was used. This nonparametric test revealed no association between output and price instability.

The finding that there is no association between price and output variability in these industries implies that commodities with unstable prices have unstable revenues, at least when shocks occur on the demand side of the market. That is, markets with prices that are relatively stable do not seem to be plagued by severe output fluctuations.

Construction of Measures of Market Structure and Organization

It is now necessary to construct quantitative measures for each of the factors that were singled out as possible determinants of metal-price instability in the informal analyses of chapters 4 and 5. These factors are: horizontal and vertical market structure, the importance of recycling, the importance of byproduct production, and the ease with which consumers can substitute for the commodity.[8]

Horizontal Concentration

The two standard measures of horizontal market structure, the 4-firm concentration ratio (CR_4) and the Hirschman-Herfindahl index (HHI) were

[7] To perform this test, one need only rank the commodities in terms of price variability. Fortunately, the rankings were insensitive to the method of weighting the price variances for each commodity that are shown in table 5.

[8] Recall that the stability of the using sectors was also singled out as a possible determinant of price instability. This factor is not considered here, however, because there was insufficient variation in this variable across commodities.

calculated for North American markets in each of the two time periods.[9] Only North American markets were considered, due to lack of data for other countries.

Table 6 shows the two sets of concentration indices.[10] These indices were calculated using data on firm shares of primary metal production, which can be found in the American Bureau of Metal Statistics' *Non-Ferrous Metal Data*. In general, measures of concentration vary from year to year. To obtain a value that is representative of a decade, averages of each index for two different years in each decade were calculated. The years chosen for the decade of the 1970s are 1972 and 1977, and those chosen for the 1980s are 1982 and 1985.

There are problems associated with using only North American data. Mineral commodities trade in world markets and the situation in North America may not be representative of the market as a whole. For example, when the commodity-market analyses of chapter 5 are compared to table 6, we see that the calculated indices underestimate concentration in the market for lead. In addition, concentration is overestimated in the silver market. Nevertheless, it was decided that use of the calculated indices was preferable to construction of qualitative measures such as "high" and "low".

Vertical Integration

The extent of vertical integration by firm or industry is not published. For this reason, qualitative measures are used here. Such measures are by nature subjective. Nevertheless, an attempt was made to be as objective as possible. The qualitative measures, which are shown in table 7, were obtained through discussions with the commodity specialists listed in the acknowledgement. Each ranking was therefore obtained through a consensus involving several people who are experts in the relevant market.

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9 The eight-firm concentration ratio is not very meaningful in industries with so few firms.

10 Four-firm concentration ratios have been multiplied by 100 and are therefore given in percentage terms.

Table 6

MEASURES OF HORIZONTAL CONCENTRATION AND RECYCLING ACTIVITY IN NORTH AMERICA

Commodity	CR_4[a]	HHI[b]	Scrap Cons[c] (RECYD)	Scrap Prod[d] (RECYS)
Aluminum				
70-79	70.1	0.142	0.192	0.194
80-86	64.7	0.134	0.357	0.281
Copper				
70-79	44.4	0.071	0.601	0.437
80-86	44.0	0.076	0.652	0.500
Lead				
70-79	52.2	0.098	0.645	0.520
80-86	56.6	0.113	0.639	0.550
Molybdenum				
70-79	90.1	0.378	0.006	0.003
80-86	88.8	0.287	0.012	0.006
Nickel				
70-79	96.2	0.529	0.135	0.127
80-86	96.9	0.287	0.012	0.006
Silver				
70-79	51.0	0.089	0.526	0.564
80-86	96.9	0.442	0.174	0.186
Zinc				
70-79	58.5	0.120	0.298	0.391
80-86	72.6	0.177	0.373	0.552

[a] CR_4 = 4-firm concentration ratio
[b] HHI = Hirschman Herfindahl index
[c] Scrap Cons (RECYD) = secondary recovery divided by total consumption (demand)
[d] Scrap Prod (RECYS) = secondary recovery divided by total production (supply)

In table 7, the symbol VI stands for the degree of vertical integration. Vertical integration is classified as being very high (VH), high (H), Medium (M), or low (L).

Importance of Recycling

Recycling activity can be measured by either secondary recovery (from old and new scrap) divided by total production (a supply measure), or by secondary recovery divided by total consumption (a demand measure). Table 6 shows both of these figures for U.S. markets in each time period. The raw data are taken from the U.S. Bureau of Mines' Mineral Yearbooks. Only the USA is considered, due to lack of data for other countries. It is hoped that recycling activity in the USA is representative of other markets.[11] Even if this is not the case, it was considered preferable to work with objective numbers instead of qualitative measures. The numbers shown in the table are averages of the relevant recycling measures, where the averages are taken over the years in each time period.

The two measures of recycling activity are not without problems. Ferroalloys such as nickel and molybdenum are usually recycled as alloys rather than being decomposed into their constituent elements. When this is the case, the quantity of the element recovered does not appear in the data. For this reason, recycling activity is underestimated for molybdenum and, to a lesser extent, for nickel.

Importance of Co and Byproducts

As with vertical integration, the only measures of the importance of coproducts and byproducts for the industry are qualitative. These estimates, which are shown in table 7 under the heading CBY, were constructed exactly as were those for vertical integration. Each number therefore represents a consensus of several experts in the field.

[11] Note that the rankings of commodities in terms of importance are more crucial for the statistical analysis than are the absolute levels of recycling activity.

Table 7

QUALITATIVE VARIABLES

Commodity	*VI*[a]	*SUBS*[b]	*CBY*[c]
Aluminum			
70-79	VH	H	L
80-86	VH	H	L
Copper			
70-79	H	H	M
80-86	M	H	M
Lead			
70-79	M	M	VH
80-86	M	M	VH
Molybdenum			
70-79	M	L	H
80-86	M	L	H
Nickel			
70-79	M	L	M
80-86	M	L	M
Silver			
70-79	M	M	VH
80-86	M	M	VH
Zinc			
70-79	L	M	H
80-86	L	M	H

[a] VI = extent of vertical integration
[b] SUBS = ease of substitution
[c] CBY = importance of coproducts and or byproducts

Ease of Substitution

Table 7 also lists qualitative measures for ease of substitution. This variable is shown in the table under the heading SUBS. The rankings under this heading are estimates of the ease with which the using sectors can employ substitute materials in their production processes when relative metal prices vary. The same remarks apply here as were made with respect to VI and CBY.

Pricing Mechanism and Time Period

Two final variables were constructed. These distinguish between pricing mechanism and time period. Each is a "dummy" variable which takes on values of either zero or one. The variable that distinguishes between pricing systems is denoted PSYS. It was set equal to one if the relevant price is a producer price and equal to zero if the price is an exchange price. The variable that distinguishes between time periods is denoted TIME. It takes on a value of zero if an observation pertains to the first decade and a value of one if it pertains to the second.

Statistical Model

Two sorts of statistical analyses are performed; the first is a regression analysis and the second is an analysis of variance. With both, the object is to relate price variability to the market-structure and organization variables just constructed.

A regression analysis is used to determine if the contribution of each factor is statistically significant. A factor is considered to be significant if its effect can be measured with statistical accuracy. The analysis of variance, in contrast, is used to determine if the contribution of each factor is important. A factor is considered to be important if its contribution to the variation in price instability across markets is relatively large. These two notions are not equivalent. For example, the effect of a factor might be measured with a high degree of accuracy while, at the same time, variations in this factor might contribute relatively little to the variability in the variable of interest.

Those uninterested in the statistical details can skip directly to the starred subsections titled "Analysis of Results" (pages 104-106 and 108).

Regression Model

Regression analysis is a statistical tool for evaluating the relationship between a variable that is to be explained (the dependent variable) and one or more independent variables. Here, the regression model relates price variability to the market-structure and organization variables.

The dependent variable, VRCP, is the variance of the rate of change of price. Values for this variable can be found in the third column in table 4. The equation that relates VRCP to the factors of interest is

$$VRCP_{ijt} = \alpha + \beta PSYS_j + \gamma HCON_{it} + \delta DS_t + \zeta SUBS$$

$$+ \eta CBY_i + \lambda RECY_{it} + \mu VI_i + \nu TIME_t + w_{ijt} \qquad (6)$$

where subscripts i, j, and t denote commodity i, sold under price system j, in time period t. The Greek letters in equation 6 denote constant parameters that are to be estimated, and the error term w has been added to indicate that the relationship is statistical and not deterministic.

The two variables HCON and RECY stand for measures of horizontal concentration and recycling activity, respectively. When equation 6 is estimated, HCON will be replaced by one of the two concentration measures, HHI or CR_4. Similarly, RECY will be replaced by one of the two recycling measures, RECYS or RECYD.

Equation 6 contains one variable that has not been defined, DS. Speculation in the silver market in the early part of the 1980 decade was very intense. In addition, this speculative activity cannot be accounted for by any of the structural or institutional factors. For this reason, a dummy variable DS was constructed that takes on a value of one for silver in the second decade and a value of zero elsewhere.

Standard regression techniques can be used to estimate equation 6. The results are shown shortly. But first, it is necessary to describe the second statistical model.

Model for Analysis of Variance

The analysis of variance is a statistical technique for analyzing measurements which depend on several kinds of effects that operate simultaneously. The object is to determine which of the effects are important and to estimate the magnitude of each.

Basically, the idea is the following. Suppose that we have a random variable, Y (in our case VRCP). We can calculate the variance of Y taken over our sample observations. We also have an equation relating Y to various causal factors, X (our equation 6). In this equation, X is a vector of variables (PSYS, HCON, DS, SUBS, CBY, RECY, VI, and TIME). The object is to decompose the variation in Y into components attributable to the X factors.

In statistics, it is often assumed that each X variable is statistically independent of every other. It is possible to make this assumption, for example, when the experiment that generated the observations was appropriately designed. In economics, however, data are rarely experimentally generated, and the assumption of statistical independence is often violated. For this reason, our analysis of variance includes an analysis of covariance.

The details of the analysis of variance are relegated to an appendix. Here it suffices to say that the variance of VRCP will be separated into three types of components: the first is a component that is attributable to variation in one of the Xs, the second is a component that is attributable to covariation between two of the Xs, and the third is a component that is purely random. The result of the application of the analysis of variance to our data is shown in the next subsection.

Empirical Results

Selection of Independent Variables

Two things must be done before the statistical models can be estimated. First, the qualitative variables VI, SUBS, and CBY must be quantified. And second, a choice must be made between the two measures of horizontal concentration, HHI and CR_4, and between the two measures of recycling activity, RECYD and RECYS.

The easiest way to quantify the qualitative variables is to assign the numbers one, two, three, and four to the classifications low, medium,

high, and very high. This procedure, however, is not altogether satisfactory. When such numbers are used in statistical analysis, the implicit assumption is that "one" is half the size of "two", one-third the size of "three", and so forth. We cannot say, in contrast, that "medium" is twice as large as "low".

To overcome this difficulty, another procedure is adopted. Terza (1987) develops a more rigorous method of quantifying ordinal qualitative variables. That is, he shows how one can convert notions such as "low", "medium", and "high" into numbers that have more comparability than "one", "two", and "three" The details of this calculation are contained in the second statistical appendix.

Correlation coefficients are used to select between two competing measures for the same explanatory factor. Table 8 lists Spearman-Rank correlation coefficients (SRCC) between the dependent variable, VRCP, and each of the explanatory variables. Spearman-Rank correlation coefficients are used instead of ordinary correlation coefficients because they depend only on rank order. It is probably the case that the conversion from qualitative to quantitative measures was less than perfectly satisfactory. As long as rankings are preserved, however, the SRCC are independent of the precise numbers assigned to each category.

Table 8

SPEARMAN RANK CORRELATION COEFFICIENTS

Variable	Correlation with VRCP
PSYS	-0.54
TIME	0.45
HHI	-0.32
CR_4	-0.30
VI	-0.10
SUBS	-0.14
CBY	0.44
RECYS	0.38
RECYD	0.32

Positive entries in table 8 denote positive covariation. That is, if the SRCC between two variables is greater than zero, these two vari-

ables tend to move in the same direction. The opposite is true for negative entries, which indicate variation in opposite directions.

The magnitude of the SRCC is also important. If the absolute value of one of two correlation coefficients is higher than that of another, the first explanatory variable is more highly correlated with the dependent variable than is the second.

This fact provides us with a means of choosing between two measures for the same factor. Using this criterion, HHI is selected as the measure of horizontal concentration and RECYS is selected as the measure of recycling activity.

Regression Results

Table 9 shows the results from applying regression analysis to equation 6. Four versions of this equation are shown. The first is just as the equation appears in the text. Each of the others is obtained from equation 6 by dropping one or more of the explanatory variables.

Table 9 should be interpreted as follows. In each equation, the numbers in the first line (those that do not appear in parentheses) are estimated coefficients. In addition, this line contains standard statistical tests for goodness of fit. These are denoted R^2, $\bar{R}^2$, and F. The second line for each equation contains t statistics for the corresponding estimated coefficients (the numbers in parentheses). A t statistic, which is a measure of statistical significance, is calculated by dividing the estimated coefficient by its estimated standard error. Starred coefficients are statistically significant.

In every estimated equation, the constant term (CON), the coefficient of the variable that distinguishes the pricing system (PSYS), and the coefficient of the variable that corrects for silver-market speculation (DS) are significant. Unfortunately, with the first version of equation 6 only these variables are significant. For this reason, alternate versions were estimated.

Table 9

REGRESSION RESULTS

#	CON α	PSYS β	HCON γ	DS δ	SUB ζ	CBY η	RECY λ	VI μ	TIME ν	R^2	$\bar{R}^2$	F
1	83.4	-24.4	-140	150	-13.0	4.7	-48.0	1.1	6.9	.90	.84	15.9
	(3.9)a	(-3.3)a	(-1.1)	(7.9)a	(-.40)	(.27)	(-.81)	(.15)	(.81)			
2	61.8	-26.2	-101	147	-14.8				2.5	.88	.85	26.0
	(6.5)a	(-3.7)a	(-2.4)b	(8.4)a	(-2.2)b				(.35)			
3	78.6	-24.4	-87.9	149		11.9	-63.5		8.2	.90	.86	23.8
	(4.5)a	(-3.6)a	(-2.1)b	(8.6)a		(2.7)a	(-2.0)b		(1.1)			
4	50.5	-28.5	-32.3	152				-2.8	.56	.86	.81	20.3
	(5.8)a	(-3.7)a	(-1.1)	(8.0)a				(-.81)	(.07)			

a denotes statistical significance at the 99% level of confidence
b denotes statistical significance at the 95% level of confidence

Each alternate equation contains the dummy variables, PSYS, DS, and TIME. In addition, it contains the measure of horizontal concentration, HCON. Of the remaining variables, equation 2 contains only those that characterize the demand side of the market, equation 3 contains only those that characterize the supply side of the market, and equation 4 contains only those that characterize the degree of vertical integration.

Table 9 shows that in the alternate specifications the demand and supply-side variables are statistically significant. The variable that measures the importance of vertical integration, however, is never significant. The analysis of variance of the next subsection will therefore use equations 2 and 3 from table 9.

Analysis of results

The regression analysis tells us that:

- producer prices are on average more stable than exchange prices;
- markets that have fewer firms have more stable prices;
- the prices of commodities that have close substitutes are more stable;
- markets where byproducts are important have unstable prices;
- markets with an important recycling sector have more stable prices.

In addition, the coefficient of the variable that corrects for speculation in the silver market is significant. All other explanatory variables have coefficients that are statistically insignificant.

Let us look at each of these findings in turn. The first confirms intuition. It is, however, at variance with other empirical evidence that suggests that the introduction of futures markets (which gives rise to both hedging and speculation) tends to stabilize prices. It is difficult to think of important factors that have not been accounted for and are systematically correlated with the choice of pricing mechanism. It therefore seems reasonable to conclude that, in these commodity markets, speculation destabilizes prices.

The second finding is both intuitive and consistent with previous empirical evidence. We therefore conclude that, with respect to horizontal concentration, metal markets are similar to other markets. In general, when there are few firms in an industry, these firms have more

control over price. The result of this control is a greater degree of stability.

The fact that ease of substitution is associated with stable prices is also not surprising. A high degree of substitutability means that production in the using sectors is more flexible. Demand is therefore more elastic, and smaller price changes are required to clear the metal market.

The destabilizing influence of coproducts and byproducts was also foreseen. Because byproduct supply is determined to a large extent by the price of the primary product, prices in markets where byproducts are important are less effective in their market-clearing role.

The stabilizing influence of secondary markets was also predicted. When recyclers are the marginal producers, their presence in an industry has the consequence of causing supply to be more price sensitive.

We saw earlier that the predicted effects of a high degree of vertical integration were ambiguous and could go in either direction. It is perhaps these conflicting influences that cause the coefficient of the measure of vertical integration to be insignificant in every equation estimated.

The predicted effects of the time-period variable were also ambiguous. The higher rates of inflation experienced in the first decade would cause metal prices to be more unstable in the 1970s, whereas the higher exchange-rate volatility experienced in the second decade would cause prices to be more unstable in the 1980s. As with the measure of vertical integration, these conflicting influences probably cause the failure to detect significance.

It is interesting to note that prices were in fact more volatile in the 1980s, as shown by table 5. What the regression analysis tells us is that this greater instability is virtually entirely explained by changes in the underlying structural variables. This finding is in sharp contrast to the result for pricing system. The correlation between method of price determination and price volatility is robust and does not disappear when other factors are introduced.

Results of the Analysis of Variance

Table 10 shows the results from performing the analysis of variance. Two equations from table 9 were used in this second stage: the second and the third. The first half of the table pertains to the variance components, whereas the second half pertains to the covariance components. Column one lists the explanatory factors and pairs of factors.

The second column in the table allows the reader to make the connection between the statistical appendix and the results shown here. Columns three and five list the estimates of the magnitude of the components. These components must sum to the total variance of VRCP, which is the number 1723 in the last row of the table. More importantly, columns four and six list the percent of the total variation in the dependent variable that is attributable to each of the explanatory factors. The percentage numbers must sum to 100.

Variables not shown, such as the dummy variable for silver-market speculation and the time variable, are considered to be random noise. This means that the noise component is large. For example, the coefficient of the speculative variable DS is highly significant. However, because DS does not measure a predictable structural or institutional factor, it is classed as a random event.

A component is (somewhat arbitrarily) classified as important if it explains at least five percent of the variation across commodities and markets in the measure of price volatility. Important components are starred in the table.

Analysis of Results

In spite of the very large pure random component in each equation, each of the structural variance components is seen to be important. That is, all of the factors that were found to be statistically significant in the regression analysis also explain a significant fraction of the variation in the measure of price volatility across markets and marketing arrangements.

In addition, three covariance components are seen to be important. These are the components associated with the covariance between horizontal concentration and ease of substitution, between horizontal concentration and recycling activity, and between recycling activity and the importance of byproducts. Let us look at each of these covariance components in turn.

Table 10

ANALYSIS OF VARIANCE

		Equation 2		Equation 3	
Name	Component	Estimate	Percent	Estimate	Percent
Variances					
Pricing System	$\beta^2\sigma_P^2$	179.2	10.4*	155.3	9.0*
Concentration	$\gamma^2\sigma_H^2$	169.3	9.8*	128.6	7.5*
Substitutability	$\zeta^2\sigma_S^2$	143.0	8.3*		
Byproducts	$\eta^2\sigma_B^2$			126.4	7.3*
Recycling	$\lambda^2\sigma_R^2$			161.4	9.4*
Covariances					
Price = Concen.	$2\beta\gamma\sigma_{PH}$	16.6	1.0	13.5	0.8
Price-Subs.	$2\beta\zeta\sigma_{PS}$	20.2	1.2		
Concen.-Subs.	$2\gamma\zeta\sigma_{HS}$	-235.6	-13.7*		
Price-Byprod.	$2\beta\eta\sigma_{PB}$			42.2	2.4
Price-Recy.	$2\beta\lambda\sigma_{PR}$			-17.2	-1.0
Concen.-Byprod.	$2\gamma\eta\sigma_{HB}$			44.9	2.6
Concen.-Recy.	$2\gamma\lambda\sigma_{HR}$			-212.4	-12.3*
Byprod.-Recy.	$2\eta\lambda\sigma_{BR}$			-134.0	-7.8*
Noise	σu^2	1430.0	83.0	1414.3	82.1
Total	σv^2	1723.0	100.0	1723.0	100.0

* denotes on important effect.

The first tells us that the importance of horizontal concentration in determining price variability is reduced when substitution is easy. This finding has intuitive appeal. What it says is that when there are close substitutes for a commodity, our calculated measure of horizontal market concentration overestimates the degree to which producers can control the market.

The second finding has a very similar interpretation. It tells us that when there is a strong secondary sector, our calculated measure of horizontal concentration for the primary sector also overestimates the degree of control that producers can exert over the market.

Finally, the price stabilizing and destabilizing effects of secondary and byproduct production tend to cancel each other. Recall that a strong recycling sector leads to more elastic supply, whereas the presence of byproducts has the opposite effect. The importance of this covariance component, therefore, also has an intuitive interpretation.

7. CONCLUSIONS

An attempt has been made to explain why producer prices have weakened in the last decade and to assess the consequences of increased reliance on metal exchanges. It should be clear by now that the choice of pricing mechanism is determined to a large extent by structural conditions within the industry. It is therefore a decision that is to some extent outside the hands of the producers.

The last 15 years have witnessed a decline in the horizontal concentration of all commodity markets considered except for lead and zinc. It is therefore not surprising that these two exceptions are the industries where the producer price seems to be relatively more viable.[1] In addition, in most metal markets the degree of vertical integration has declined, recycling has gained in importance, and the extent of both international integration and government participation has risen. A combination of these factors will inevitably result in increased reliance on well-organized commodity exchanges.

On average, prices were seen to be more unstable in the 1980s than in the 1970s. This difference, however, was entirely explained by changes in underlying economic and organizational factors, the most important of these being increased reliance on metal exchanges. When these changes were accounted for, the difference in volatility across time periods disappeared entirely.

The results for pricing mechanism are very different from those for time period. This statistical regularity did not disappear when the more complex model was estimated. In fact, the most robust conclusion of the statistical analysis is that, even after the changes in market structure that led to greater price instability have been accounted for, prices determined on metal exchanges are more volatile than those set by producers.[2] Increased price instability in markets that were already noted for chronic gluts and shortages must be considered a drawback.

A priori, increased price volatility need not be associated with increased revenue instability. Revenue stability would be unrelated to price stability across markets if, for example, in some industries price

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[1] Even in the lead market, however, the producer price is substantially weakened.

[2] The complete set of results of the statistical analyses are summarized on pages 104-106 and 108. They are therefore not resummarized here.

bore the brunt of adjusting to fluctuations in demand, whereas in others output performed this role. In the markets studied here, however, commodities with more stable prices do not seem to suffer from increased production instability.

In spite of the drawbacks, the switch to exchange-based pricing has many benefits. Perhaps the most important advantage is the introduction of hedging, which provides insurance to both buyer and seller. In addition, the absorption of unwanted inventories must be considered a plus. These highly desirable features of commodity exchanges must therefore be weighed against their substantial costs.

It is perhaps surprising that, in sharp contrast to price volatility, the choice of pricing system was found to be unrelated to the level of prices. According to the conventional wisdom, prices set by oligopolists should be higher than those determined in auction markets. Producers with market power, however, may find it in their interest to protect consumers from speculative bubbles. If a sharp run-up in price causes consumers to substitute away from metals in favor of commodities with more stable prices, it may be in the long-run interest of oligopolistic firms to insulate their customers from the vagaries of commodity markets.

Because there are costs and benefits associated with any pricing system, it is clear that no one arrangement is ideal for all commodities. The variety of arrangements that currently exists is therefore a virtue and not a flaw. And, as metal markets continue to undergo reorganization, the institutions that govern their prices will continue to evolve.

In the last decade, we have seen fundamental changes in metal pricing. Not only has there been a switch to increased reliance on commodity exchanges, these exchanges have themselves undergone radical reorganization. It is hoped that this descriptive summary and economic assessment of metal pricing as it exists today will serve to clarify some of the issues and decisions that the nonferrous metal producers must confront.

A: STATISTICAL APPENDIX

Treatment of Qualitative Independent Variables

The treatment of ordinal qualitative independent variables in regression equations follows Terza.[3] An ordinal qualitative variable is characterized by a continuous unobservable ordinal latent index L whose range is partitioned into J intervals. Each interval is ranked (1 through J) in increasing order. It is assumed that the j'th qualitative outcome is observed if and only if the value of the latent index L falls within the j'th interval.

Three variables in the regression equation 2 in the text are ordinal qualitative variables; VI, which measures the degree of vertical integration; SUB, which measures the ease of substitution; and CBY, which measures the importance of coproducts and byproducts. In each case, the ordinal qualitative variable has four categories or intervals: low, medium, high, and very high. The object here is to assign numerical values to these qualitative notions in such a way as to allow for cardinal comparisons.

Here we consider a single ordinal latent index, L, and assume that L is normally distributed. We do not observe L, however. Instead we observe an ordinal qualitative variable O defined by

$$O_k = j \text{ if } \theta_{j-1} < L_k \leq \theta_j, k = 1,\ldots,K, \quad (A1)$$

where the θs are the bounds of the intervals into which L is partitioned and K is the number of observations in the sample. We wish to use the data on O to find estimates of L_k, which we denote $\hat{L}_k$.

Terza shows that such estimates can be obtained as follows. Let p_j be the percent of the sample that falls within the j'th interval. Equivalently, p_j equals the number of Os that are equal to j, divided by the total number of observations in the sample, K. An estimate of θ_j, $\hat{\theta}_j$, is then

$$\hat{\theta}_j = N^{-1}\left(\sum_{i=1}^{j} p_i\right), \quad (A2)$$

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[3] J.V. Terza, "Estimating Linear Models with Ordinal Qualitative Regressors", *Journal of Econometrics*, 1987, no. 34, pp. 275-291.

where N^{-1} stands for the inverse of the cumulative density function of a standard normal variate.

Next, define n_j and λ_j by

$$n_j = n(\theta j) \quad (A3)$$

and

$$\lambda j = (n_{j-1} - n_j)\, p_j \quad (A4)$$

where n is the density function of a standard normal variate.

Finally, the estimate of L_k, $\hat{L}_k$ is given by

$$\hat{L}_k = \lambda_j \text{ if } O_k = j \quad (A5)$$

This procedure was followed for each of the ordinal qualitative variables of interest.

Analysis of Variance

The analysis of variance is a statistical technique for analyzing measurements which depend on several kinds of factors that operate simultaneously. Suppose that we have a dependent variable Y and several independent variables X, where X is a vector. The object is to decompose the variance of Y into components attributable to each X factor. When we have performed this task, we will know which of the Xs are important contributors to the variability in Y.

In addition, if the Xs are not statistically independent, we seek to determine the joint influence on Y of each X pair. Determination of joint effects is known as the analysis of covariance.

There are many approaches to the analysis-of-variance problem. Those wishing a more complete treatment are referred to Searle.[4] Here, I will present one approach in the context of one of the variants of equation 2 in the text.

To conserve on notation, we rewrite the second version of equation 2 as

$$V_k = \alpha + \beta P_k + \gamma H_k + \delta D_k + \zeta S_k + \upsilon T_k + w_k \quad (A6)$$

---

[4] S.R. Searle, *Linear Models*. (New York: John Wiley and Sons, Inc., 1971).

where, V is the variance of the rate of change of price (VRCP in our earlier notation), P is the dummy variable that distinguishes pricing system (PSYS), H is the HH index of concentration (HCON), D is the dummy variable that corrects for speculation in the silver market (DS), S is the measure of ease of substitution (SUBS), T is the dummy variable that distinguishes time periods (TIME), and the subscript k ranges over all observations. The random error term w signifies that the relationship is stochastic. Equation A6 corresponds to the second estimated equation found in table 9.

In equation A6, P, H, and S are the structural and institutional factors whose influences we wish to evaluate. D can be considered a random event. T is not random, but its coefficient was never found to be statistically significant. We therefore rewrite A6 as

$$V_k = \alpha + \beta P_k + \gamma H_k + \zeta S_k + u_k \quad (A7)$$

where

$$u_k = \delta D_k + \upsilon T_k + w_k \quad (A8)$$

u_k is considered the noise component of V.

Taking the variance of both sides of equation A7 we obtain[5]

$$\sigma_V^2 = \beta^2\sigma_P^2 + \gamma^2\sigma_H^2 + \zeta^2\sigma_S^2 + 2\beta\gamma\sigma_{PH}$$

$$+ 2\beta\zeta\sigma_{PS} + 2\gamma\zeta\sigma_{HS} + \sigma_u^2 \quad (A9)$$

in equation A9, the symbol σ_X^2 stands for the variance of X and σ_{XZ} for the covariance between X and Z, where X and Z are arbitrary random variables.

Equation A8 is the relationship sought. It decomposes the variance of V, σ_V^2, into three sorts of components: 1) the variance components (the first three expressions after the = sign); 2) the covariance components (the next three expressions); and 3) the noise component (σ_u^2).

Estimates of the coefficients β, γ, and ζ can be found in the second row of table 9. Sample variances for the dependent variable and each independent variable can be calculated from the data. Similarly, sample covariances can be calculated for each X pair. With these estimates, it

[5] Notice that we are implicitly assuming that the independent variables P, H, and S are stochastic. As long as they are not correlated with w, however, this does not create a problem for the regression analysis.

is possible to evaluate each component of equation A9. These are the numbers shown under the heading "equation 2" in table 10.

The same technique (using regression equation 3 from table 9) can be used to obtain the components that are found under the heading "equation 3" in table 10.

B: DATA APPENDIX

Abbreviations and Sources

ABMSY: *American Bureau of Metal Statistics Yearbook*
Note: The title was changed to NFMD in 1974. References to NFMD refer either to NFMD or ABMSY.

IFS: *International Financial Statistics*

LME: London Metal Exchange (These are computer printouts)

MANTHY: Manthy, R (1978) *Natural Resources Commodities - A Century of Statistics*, Baltimore: Johns Hopkins University Press.

MS: *Metal Statistics*

MSk: *Metallstatistik*, from Metallgesellschaft A.G., Frankfurt am Main

MW: *Metals Week*, Annual Price Handbook

NFMD: *Non-Ferrous Metal Data*
Note: NFMD refers either to NFMD or ABMSY.

PC: Potter N. and Christy, F.T., *Trends in Natural Resource Commodities*, Statistics of Prices, Output, Consumption, Foreign Trade, and Employment in the United States, 1870-1957. (Baltimore: Johns Hopkins University Press, 1962).

TMT: thousands of metric tons

TST: thousands of short tons (2000 lbs average)

WWorld: western world; excludes communist-block countries.

Conventions

In a datafile, a value of -1.0 indicates that the observation is missing and that it may be updated if the information is found. A value of -2.0 indicates that there is no such observation but a value is still entered for padding purposes. Entries in this file should reflect the reason why the series does not include these observations.

Conversion for Weights

1 short ton = 2000 lb
1 metric ton = 2204.62 lb
1 troy ounce = 1.0971428 avoirdupoids ounce
1 troy ounce = 0.0685714 avoirdupoids pounds
1 lot (silver) = 10000 troy ounces

Aluminum

ALUM.PRICE - Aluminum Prices, monthly, 1970-86

col 1 *Metals Week* U.S. prices, 1972-86, US cents/lb
Sources: 1972-78, MW, Annual Price Handbook
1979-86, Printout from Alcan, converted from US$/MT
col 2 LME prices, 1979-86, U.S. cents/lb, 99.5% ingots
Source: NFMD
col 3 North American producer prices, 1970-85, U.S. cents/lb
Source: NFMD

Note: This series was originally called "Producer prices in New York"; in Jan 1981 the name was changed to "U.S. Aluminum Prices". Beginning in Jan 1986, *Metals Week's* U.S. market prices are used in the source so 1986 is set to -2.0.

ALUM.OUTPUT - output of aluminum, 1970-86

Production of Bauxite, TST

col 1 WWorld
col 2 USA (dried equivalent of crude ore)
col 3 Canada
col 4 North America (col 2 + col 3)

Sources: 1970-73, NFMD74, p. 88
1974-77, NFMD78, p. 88
1978-81, NFMD82, p. 88
1982-86, NFMD86, p. 88

Production of Primary Aluminum, TST

col 5 WWorld
col 6 USA
col 7 Canada
col 8 North America (col 6 + col 7)

Sources: 1970-73, NFMD74, p. 89
1974-77, NFMD78, p. 89
1978-81, NFMD82, p. 89-90
1982-86, NFMD86, p. 89-90

Consumption of Primary Aluminum, TST

col 9 WWorld
col 10 USA
col 11 Canada
col 12 North America (col 10 + col 11)

Sources: 1970-73, NFMD74, p. 90
1974-77, NFMD78, p. 90
1978-81, NFMD82, p. 90-91
1982-86, NFMD86, p. 90-91

Copper

COPP.PRICE - copper prices, 1970-86, monthly, U.S. cents lb

col 1 Producer prices of electrolytic copper, 1970-1985
Source: MS
col 2 LME prices, 1970-86
Source: NFMD
Note: From July 1986, Grade A Settlement price.

COPP.OUTPUT - output of copper, 1970-86

Mine Production of Copper, TST

col 1 WWorld
col 2 USA
col 3 Canada
col 4 North America (col 2 + col 3)

Sources: 1970-73, NFMD74, p. 9
1974-77, NFMD78, p. 9
1978-81, NFMD82, p. 9
1982-86, NFMD86, p. 9

Refined Production of Copper, TST

col 5 WWorld
col 6 USA
col 7 Canada
col 8 North America (col 6 + col 7)

Sources: 1970-73, NFMD74, p. 11
1974-77, NFMD78, p. 11
1978-81, NFMD82, p. 11
1982-86, NFMD86, p. 11

Refined Consumption of Copper, TST

col 9 WWorld
col 10 U.S.
col 11 Canada
col 12 North America (col 10 + col 11)

Sources: 1970-73, NFMD74, p. 12
1974-77, NFMD78, p. 12
1978-81, NFMD82, p. 12-13
1982-86, NFMD86, p. 12-13

Lead

LEAD.PRICE - lead prices, 1970-86, monthly, U.S. cents/lb

col 1 LME prices
Source: NFMD
col 2 U.S. producer lead prices
Source: NFMD
Note: Effective Dec. 1971, one delivered price nationwide replaced delivered New York basis quotation. Beginning Oct. 1986, North American producer price; prior, U.S. producer price.

LEAD.OUTPUT - output of lead, 1970-86

Mine Production of Lead, TST

Note: Starting in 1977 the series reflects "lead content by analysis of lead ores and concentrates plus the lead content of other ores and concentrates known to be intended for lead recovery". See individual columns for meaning for 1970-77.

col 1 WWorld (see notes for col 2 and col 3)
col 2 U.S. (from 1970-77, footnotes indicate "calculated as recoverable")
col 3 Canada (from 1970-77, footnotes indicate "Base bullion from domestic ores plus recoverable content of ore exported")
col 4 North America (col 2 + col 3)

Sources: 1970-73, NFMD74, p. 45
1974-77, NFMD78, p. 45
1978-81, NFMD82, p. 45
1982-86, NFMD86, p. 45

Refined Production of Lead, TST

Note: 1970-73: entries reflect smelter production. U.S. figures are the sum of foreign and domestic. Footnote for the U.S. domestic figures is "Smelter's original production from domestic ores, including some secondary". 1974-77: entries reflect refined production of primary lead. 1978-86: entries reflect refined production that includes all secondary refined metal. There is a definite break in the compatibility of the series after 1978.

col 5 WWorld
col 6 USA
col 7 Canada
col 8 North America (col 6 + col 7)

Sources: 1970-73, NFMD74, p. 46
1974-77, NFMD78, p. 46
1978-81, NFMD82, p. 46-47
1982-86, NFMD86, p. 46

Refined Consumption of Lead, TST

Note: 1970-77: consumption of primary. 1978-86: refined consumption that includes all secondary refined metal. There is a definite break in the compatibility of the series.

col 9 WWorld
col 10 USA
col 11 Canada
col 12 North America (col 10 + col 11)

Sources: 1970-73, NFMD74, p. 47
1974-77, NFMD78, p. 47
1978-81, NFMD82, p. 47-48
1982-86, NFMD86, p. 47-48

Molybdenum

MOLY.PRICE - molybdenum prices, 1970-86, monthly, U.S. cents/lb

col 1 Molybdenum concentrate (Climax), 1970-85
Source: MS
col 2 Dealer oxide prices (Low), 1970-85
Source: MW
col3 Dealer oxide prices (High), 1970-85
Source: MW
col 4 (col 2 + col 3)/2 for 1970-85
Note: 1986 from MW. Yearbook entries are slightly different from those found in this column prior to 1986.

MOLY.OUTPUT - output of molybdenum, 1970-86

Mine Production of Molybdenum, 1000 lbs

col 1 WWorld
col 2 USA
col 3 Canada (shipments)
col 4 North America (col 2 + col 3)

Sources: 1970, MS75, p. 172
1971-74, MS76, p. 158
1975-76, MS80, p. 140
1977-79, MS83, p. 126
1980-84, MS86, p. 113
1985-86, NFMD86, p. 119

Nickel

NICK.PRICE - nickel prices, 1970-86, monthly, U.S. cents/lb

col 1 Monthly average prices of nickel
Source: NFMD
Note: Missing observation for Aug. 1977, replaced by the value for July 1977. In 1986, series name changed to "Canadian Producer Nickel Prices".

col 2 LME cash nickel price. Aug. 1979 - Dec. 1986
Source: MW
Note: Original data was in UK pounds MT and was transformed to U.S. cents lb.

NICK.OUTPUT - output of nickel, 1970-1985

Mine Production of Nickel, TST

col 1 WWorld
col 2 USA "Recovered nickel content by ferronickel and byproduct in copper refineries".)
col 3 Canada
col 4 North America (col 2 + col 3)

Sources: 1970-74, MSk1970-80, p. 55
1975-85, MSk1975-85, p. 59

Refined Production of Nickel, TST

Note: 1970-74: "Primary nickel and nickel contained in ferronickel, nickel oxide sinter and monel metal smelted directly from ores". From 1975-85: "Primary nickel and nickel contained in ferronickel, nickel oxide sinter and monel metal smelted directly from intermediate products". In the 1975-85 source, the title of the series was changed from "Production of refined nickel" to "Nickel Smelter Production". The series were found to be compatible.

col 5 WWorld
col 6 USA
col 7 Canada
col 8 North America (col 6 + col 7)

Sources: 1970-74, MSk1970-80, p. 56
1975-85, MSk1975-85, p. 57

Consumption of Nickel, TST

Note: Including nickel content in ferronickel and nickel oxide sinter, excluding consumption of nickel chemicals.

col 9 WWorld
col 10 USA
col 11 Canada
col 12 North America (col 10 + col 11)

Sources: 1970-74, MSk1970-80, p. 57
1975-85, MSk1975-85, p. 59

Silver

SILV.PRICE - silver prices, 1970-86, monthly, U.S. cents per troy ounce

col 1 Prices in New York (Handy & Harman)
Source: 1970-85, MS
1986 MW86, p. 208
col 2 LME Prices
Note: Monthly average price of official LME quotations for .999 bar silver 10,000 troy ounce contracts. Data was originally in pence per troy ounce, was converted to U.S. cents per troy ounce.
Source: 1970-85, MS.
1986, MW86, p. 215, "LME Cash"

SILV.OUTPUT - output of silver, 1970-86

Mine Production of Silver, TMT

col 1 WWorld
col 2 USA
col 3 Canada
col 4 North America (col 2 + col 3)

Sources: 1970-71, MSk1961-71, p. 45
1972-74, MSk1972-82, p. 62
1975-85, MSk1975-85, p. 62
1986, NFMD86, p. 100. (numbers were compatible)

Refined Production of Silver, TST

Note: 999 Fine

col 5 WWorld: no data could be found
col 6 USA: primary (from ores, concentrates, etc.)
Note: series starts in 1972, could not find 1970-71 elsewhere.
col 7 Canada: no data could be found
col 8 North America (col 6 + col 7)

Sources: 1972-73, NFMD74, p. 107
1974-77, NFMD78, p. 107
1978-81, NFMD82, p. 107
1982-86, NFMD86, p. 106

Consumption of Silver, million troy ounces

Note: this is consumption for industrial use. Consumption for coinage is not included.

col 9 WWorld
col 10 USA
col 11 Canada
col 12 North America (col 10 + col 11)

Sources: 1970-73, NFMD74, p. 102
1974-77, NFMD78, p. 101
1978-81, NFMD82, p. 101
1982-86, NFMD86, p. 101

ZINC

ZINC.PRICE - zinc prices, 1970-86, monthly, U.S. cents/lb

col 1 Prime Western zinc prices in New York, 1970-85
Source: MS
Note: In Sept. 1980 domestic producers changed their pricing structure to make High Grade the base grade, with premiums for all other grades, including Prime Western. 1986 = Noranda Sales list price, from printed outputs.
col 2 LME prices
Source: NFMD
col 3 Producer basis outside North America (EEP)
Source: obtained from Noranda
1970-75 was in UK pounds/MT. It was transformed to U.S. cents/lb. 1976-79 was transformed from US$/MT. 1980-86 was transcribed as is.

ZINC.OUTPUT - output of zinc, 1970-86

Mine Production of Zinc, TST

Note: Starting in 1985 the series reflects "Zinc content by analysis of zinc ores and concentrates, plus the zinc content of other ores and concentrates known to be intended for zinc recovery". Before 1985, no special mention. A check indicates that the series are compatible.

col 1 WWorld
col 2 USA
col 3 Canada
col 4 North America (col 2 + col 3)

Sources: 1970-73, NFMD74, p. 67
1974-77, NFMD78, p. 67
1978-81, NFMD82, p. 67
1982-86, NFMD86, p. 65

Refined Production of Zinc, TST

col 4 WWorld
col 5 USA
col 6 Canada
col 7 North America (col 5 + col 6)

Sources: 1970-73, NFMD74, p. 68
1974-77, NFMD78, p. 68
1978-81, NFMD82, p. 68-69
1982-86, NFMD86, p. 66

Refined Consumption of Zinc, TST

Note: Starting in 1980, series title was changed from "World consumption of slab zinc" to "World refined consumption of slab zinc". This seems to be only a change in title; a check of data indicates that the series is compatible.

col 7 WWorld
col 8 USA
col 9 Canada
col 10 North America (col 8 + col 9)

Sources: 1970-73, NFMD74, p. 69
1974-77, NFMD78, p. 69
1978-81, NFMD82, p. 69-70
1982-86, NFMD86, p. 67

Exchange Rates and Price Indices

USEXRATES - US exchange rates, monthly, Jan 1970-May 1987

Market rates, period averages
Source: IFS database
col 1 U.S.$ per Canadian $
col 2 U.S.$ per Pounds
col 3 U.S.$ per DM
col 4 U.S.$ per Yen

EXCHANGE - U.S.-Canadian dollar exchange rates, annual, 1870-1985
Canadian $ per one U.S. $.

WPUS.ANN - Wholesale price index, U.S., annual, 1870-1986
Source: Historical Statistics of the U.S.
1870-1890, Warran Pearson Price Index
1891-1985, Bureau of Labour Statistics
RP: 1986, IFS, May 1987, p. 516, series
(1.115*2.688 = 2.997, using index for 1980)

WPUS.MTH - U.S. Wholesale price index, monthly, Jan 1970-Dec 1985
Source: CITIBASE data base, originally from BLS

US INFLATION - U.S. inflation rate monthly, Jan 1970-Dec 1986
Calculated as ln(WPI(t))-ln(WPI(t-1)).

Historical Data on Prices

HISTMET1 - Nominal metal prices, annual, 1870-1986

col 1 copper: 1870-86, U.S. cents/lb
Sources: 1878-73, MANTHY, p. 114, 1870-1954, PC, p. 342
1955-73, ABMSY, monthly average prices of copper, domestic refinery-New York
1974-86, NFMD86, p. 140. yearly average of U.S. producer copper refinery

col 2 lead: 1870-86, U.S. cents/lb
Sources: 1878-73, MANTHY, p. 114, 1870-1954, PC, p. 343
1955-73, MY, average U.S.
1974-86, NFMD86, p. 139, U.S. producer price

col 3 Silver: 1870-86, U.S. cents per fine troy ounce
Sources: 1870-1897, MY
1898-1935, MS36, p. 488, silver prices in NY
1936-44, MS76, p. 186, silver prices in NY
1945-85, MS86, p. 138, silver prices in NY
1986, NFMD86, p. 107

col 4 nickel: 1913-1986, U.S. cents/lb
Sources: 1913-55, Schurr, S.H., *Historical Statistics of Minerals in the U.S.*, Resources for the Future Inc., p. 19
1956-78, NFMD, monthly average prices
1979-85, LME average price
1986, LME cash average price, MW86

col 5 zinc: 1870-1985, U.S. cents/lb
Sources: 1870-1973, MANTHY, p. 114
1870-1954, PC, p. 344
1955-73, MS, Prime Western Zinc prices in New York
1974-85, MS86, p. 210
1986, Noranda Sales List Prices, averaged from printed outputs.

col 6 moly: 1914-1985, U.S. cents/lb
Sources: 1914-1973, MANTHY, p. 114
1914-54, PC, p. 337
1955-70, Statistical Abstracts
1970-85, dealer oxide average price
1986, MW86, p. 150

col 7 alum: 1895-1985, U.S. cents/lb
Sources: 1895-1907, NFMD, p. 104
1908-55, NFMD57, p. 135
1956-78, NFMD86, p. 139
1979-85, MW average price
1986, MW86, p. 35; "MW US Market"

LME Data

LME.INV LME inventories, Monthly from Dec 1977 to Dec 1986
Yearly figures are same as December.

Source: Rudolf Wolff & Co. Ltd. London
var 1: copper, 3 months (London), in TMT
var 2: lead, 3 months (London), in TMT
var 3: zinc high grade, 3 months, in TMT
var 4: zinc, 3 months (London), in TMT
var 5: LME silver, 3 months, silver units unknown
var 6: LME aluminum, 3 months, in TMT
var 7: nickel, 3 months (London), in TMT

LME.SALES LME sales volume, yearly, from 1974 to 1986

Source: Rudolf Wolff & Co. Ltd. London
var 1: copper, 3 months (London), MT
var 2: lead, 3 months (London), MT
var 3: zinc high grade, 3 months, MT
var 4: zinc, 3 months (London), MT
var 5: LME silver, 3 months, units unknown
var 6: LME aluminum, 3 months, MT
var 7: nickel, 3 months (London), MT

The Author

Margaret Slade was born in Middlebush, New Jersey in 1940 and obtained her Bachelor's degree in mathematics from Vasser in 1961. In 1963 she earned her M.A. in mathematics from the University of California at Berkeley. After serving as a mathematican in several positions in both the United States and New Zealand, she obtained her Ph.D. in economics from The George Washington University in Washington, D.C. in 1979. Since 1981 she has taught and conducted economic research at the University of British Columbia where she is an Assistant Professor in the Department of Economics. She has published numerous studies in the areas of natural resource economics, industrial organization, and applied econometrics.

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